

Contemporary Diabetes
Series Editor: Aristidis Veves

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John M. Giurini
Raul J. Guzman *Editors*

The Diabetic Foot

Medical and Surgical Management

Fourth Edition

 Humana Press

Contemporary Diabetes

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ISSN 2197-7836 ISSN 2197-7844 (electronic)
Contemporary Diabetes
ISBN 978-3-319-89868-1 ISBN 978-3-319-89869-8 (eBook)
<https://doi.org/10.1007/978-3-319-89869-8>

Library of Congress Control Number: 2018949324

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Printed on acid-free paper

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface to the Fourth Edition

We are proud to present the fourth edition of our standard textbook *The Diabetic Foot* 5 years after its previous version. As in prior editions, we have tried to highlight new developments in our understanding of diabetic foot physiology and its clinical management. In order to best achieve our aim, we have divided the book into four sections, the first focusing on clinical features and diagnosis, the second on pathophysiology, and the third on the management of diabetic foot problems and the fourth on organization and preventive care. In addition to updating prior chapters, we have added several new contributions that reflect advances in our understanding of the causes of diabetic foot ulcers and efforts to develop new and more effective therapies.

In the 5 years since the last edition, it has become even more evident that the diabetes pandemic continues unabated, with millions of additional cases diagnosed each year. There is therefore no doubt that intense efforts by health care professionals and provider organizations throughout the world to develop clinical programs that can provide efficient and affordable diabetic foot care will be required. To this end, we hope our efforts in this book will help provide the necessary basics as we include fundamental principles for managing diabetic foot problems that have developed over five decades at the Joslin-Beth Israel Deaconess Diabetic Foot Center, one of the very first centers to focus on this condition in a systematic and multidisciplinary fashion.

As time goes by, changes in our editorial leadership occur as a matter of course. The replacement of Dr. Frank W. LoGerfo, co-editor in all three previous editions, by Dr. Raul J. Guzman in this edition is one such change. Dr. LoGerfo has recently retired from clinical practice and as such felt that it would be best to step down as co-editor and pass the baton to Dr. Guzman. First, we would like to thank Dr. LoGerfo for all of his significant contributions to this project over the years. We also want to recognize his noteworthy accomplishments related to care of the diabetic foot ulcer patient as it is common knowledge that without his early pioneering work, the surgical management of these patients would not have attained its current level of success. Finally, we would like to wish him every success in his future research and nonacademic endeavors. We also want to welcome Dr. Guzman, a vascular surgeon with extensive experience in managing diabetic foot ulcer patients and research interests in the pathophysiology of pedal ischemia, as our new co-editor for this edition.

We believe that the fact that we are publishing the fourth edition since the first was published in 2002 speaks loudly to the success of the previous efforts. We hope that the current edition will be equally successful and that it will help our diabetic foot patients receive better care and see tangible results in their fight to preserve an intact and functional lower extremity. As with the previous edition, we want to sincerely thank all the authors for their hard work in providing outstanding chapters. We also want to express our gratitude to Humana Press for their continuing support of this project.

Boston, MA, USA
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Aristidis Veves, MD, DSc
John M. Giurini, DPM
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Part I

Clinical Features and Diagnosis



Epidemiology and Health Care Cost of Diabetic Foot Problems

1

Robert G. Frykberg, Jeremy J. Cook,
and Donald C. Simonson

Abstract

The diabetic lower extremity has long been a cause for both morbidity and mortality in patients afflicted with this multisystem disease. Unfortunately, the global prevalence of diabetes mellitus has been projected to nearly double from a baseline of 2.8% in 2000 to 4.4% by 2030, affecting over 350 million individuals (Wild et al. *Diabetes Care*. 2004;27(5):1047–53). In the decade beginning in 1997, the prevalence of diabetes in the USA has increased by 48% (<http://apps.nccd.cdc.gov/DDTSTRS/default.aspx>). Lower extremity morbidity contributes substantially to the toll diabetes takes on the individual and the health care system. This chapter focuses on the epidemiologic aspects of risk factors and complications in the diabetic lower extremity, particularly as they relate to the outcome of amputation. Included in the discussion is the influence of demographic factors, such as gender, age, race, and socioeconomic considerations, as well as the cost to the health care system of lower extremity disease in diabetes.

clinical acumen he was able to ascertain, even in the early twentieth century, those risk factors that placed the diabetic lower extremity at risk for ulceration, gangrene, and amputation. Many years later in 1992, Zimmet first referred to the “epidemic of diabetes,” noting that its costs both in terms of economic burden and human suffering are rising at an alarming rate [2]. The global prevalence of diabetes mellitus has been projected to nearly double from a baseline of 2.8% in 2000 to 4.4% by 2030, affecting over 350 million individuals [3]. In the decade beginning in 1997, the prevalence of diabetes in the USA has increased by 48% [4] (Fig. 1.1). An estimated 29 million or 9.3% of people living in the USA are affected by diabetes mellitus, with its prevalence and costs continuing to increase [5]. In the years 2007 to 2013 the prevalence of diabetes increased by 26% with associated costs of this disease increasing by 41% [6, 7]. The total estimated cost of diabetes in 2012 was \$245 billion, with 43% of costs attributed to inpatient care. Compared to people without diabetes, the medical expenditures are approximately 2.3-fold higher for diabetic persons [7]. Lower extremity morbidity contributes substantially to the toll diabetes takes on the individual and the health care system. In fact, of the 785 million ambulatory diabetes-related outpatient visits between 2007 and 2013, approximately 6.7 million visits (0.8%) were for diabetic foot ulcers (DFU) or infections. DFU visits were associated with a 3.4 greater odds of direct Emergency department or inpatient admission [8]. This chapter focuses on the epidemiologic aspects of risk factors and complications in the diabetic lower extremity, particularly as they relate to the outcome of amputation. Included in the discussion is the influence of demographic factors, such as gender, age, race, and socioeconomic considerations, as well as the cost to the health care system of lower extremity disease (LED) in diabetes.

Introduction

In his landmark paper of 1934, Elliott P. Joslin lamented on the “Menace of Diabetic Gangrene” and how its frequency was increasing among his patients [1]. With his keen insights and

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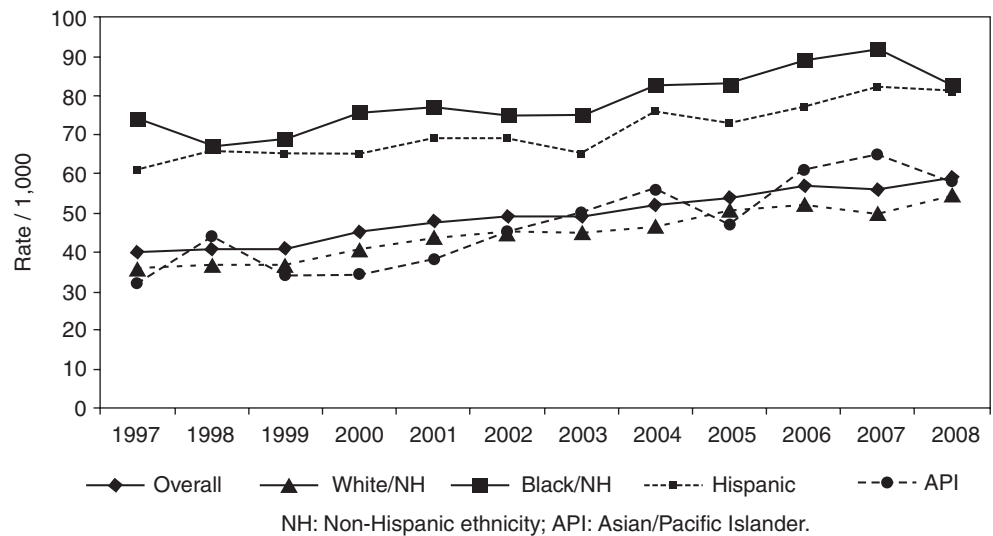
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Epidemiology of Individual Risk Factors

The individual systems at risk that predispose an individual to ulceration are covered in greater detail throughout this

Fig. 1.1 Diabetes prevalence [4]



textbook. In this chapter, a brief introduction to these risk factors is presented as they relate to the epidemiology of the at-risk foot.

Neuropathy

A frequently encountered complication of diabetes mellitus is neuropathy. Diabetic peripheral neuropathy (DPN) is an impairment of normal activities of the nerves throughout the body and can alter autonomic, motor, and sensory functions [9]. The reported prevalence of DPN ranges from 16% to as high as 66% [10–14]. According to a study utilizing National Health and Nutrition Examination Survey (NHANES) data of 2873 noninstitutionalized adults aged 40 years and older, the prevalence of peripheral neuropathy in people with diabetes ($n=419$) was 28.5% (95% CI 22.0–35.1). The prevalence of peripheral neuropathy in people with diabetes was almost twice as high as in those without diabetes (14.8% (95% CI 12.8–16.8)) [15]. Another study utilizing NHANES data found that the incidence of peripheral neuropathy was higher in people with undiagnosed (16.6%) and diagnosed (19.4%) diabetes when compared to people without diabetes or with impaired fasting glucose levels between 100 and 125 mg/dL [16]. In the mid-1990s, the annual incidence of peripheral neuropathy was nearly equivalent between genders, but more recent data have shown a growing gap with male incidence climbing [17] (Fig. 1.2).

Although many manifestations of neuropathy may go unrecognized by the patient, autonomic neuropathy is perhaps the most overlooked in the diabetic limb. In addition to contributing to impaired vasoregulation, it also may result in changes to the texture and turgor of the skin, such as dryness and fissuring. Dysregulation of local perspiration may contribute to increased moisture and increase the risk of fungal

infections. With increased stiffness within the skin, areas of friction are less flexible and hyperkeratotic lesions may develop. Untreated, these lesions may progress with respect to thickness and induration, and exert increased pressure on deep tissues with resultant ulceration [18, 19].

Another form of neuropathy that influences the diabetic limb is reduced motor function. Frequently, this targets the intrinsic musculature of the foot resulting in joint instability. As innervation decreases, muscle wasting is observed. Over time, these imbalances lead to flexible deformities that become progressively more rigid. Rigid deformities are subject to greater pressure and predispose patients to ulcer formation [9].

Perhaps the most commonly recognized form of neuropathy among patients with diabetes is sensory neuropathy, resulting in the loss of sensation beginning in the most distal part of the extremity. This may manifest as an inability to detect temperature changes, vibration, proprioception, pressure, and, most seriously, pain. Some patients have a form of painful sensory neuropathy that includes symptoms, such as burning and tingling, known as paresthesias. This also contributes to the risk of ulcer formation as they may be unaware of pain associated with smaller injuries because of the persistent neuropathic pain [9]. The prevalence of painful DPN is difficult to truly measure and define. NHANES estimated that 10.9% of adults with diabetes suffered from symptomatic DPN. Symptomatic DPN was defined as painful sensations, tingling, numbness, or loss of feeling. A population-based study through the Mayo clinic found that 20% of their diabetic cohort had painful DPN [10]. In the UK, the prevalence of chronic painful DPN was found to be 16.2% [20] and the incidence, through a UK research database, was 15.3/100,000 patient-years (95% CI 14.9–15.7) [21]. Although there is a lack of high-quality data available from a population health perspective, the prevalence of DPN