



# **Diabetic Foot Complications**

A Global Outlook

Rex Slavin  
Windy Wise  
Roy Marcus Cohn

# Diabetic Foot Complications: A Global Outlook

Edited by **Rex Slavin, Windy Wise and  
Roy Marcus Cohn**



hayle  
medical

New York

Published by Hayle Medical,  
30 West, 37th Street, Suite 612,  
New York, NY 10018, USA  
www.haylemedical.com

**Diabetic Foot Complications: A Global Outlook**

Edited by Rex Slavin, Windy Wise and Roy Marcus Cohn

© 2015 Hayle Medical

International Standard Book Number: 978-1-63241-106-8 (Hardback)

This book contains information obtained from authentic and highly regarded sources. Copyright for all individual chapters remain with the respective authors as indicated. A wide variety of references are listed. Permission and sources are indicated; for detailed attributions, please refer to the permissions page. Reasonable efforts have been made to publish reliable data and information, but the authors, editors and publisher cannot assume any responsibility for the validity of all materials or the consequences of their use.

The publisher's policy is to use permanent paper from mills that operate a sustainable forestry policy. Furthermore, the publisher ensures that the text paper and cover boards used have met acceptable environmental accreditation standards.

**Trademark Notice:** Registered trademark of products or corporate names are used only for explanation and identification without intent to infringe.

Printed in China.

# Preface

The world is advancing at a fast pace like never before. Therefore, the need is to keep up with the latest developments. This book was an idea that came to fruition when the specialists in the area realized the need to coordinate together and document essential themes in the subject. That's when I was requested to be the editor. Editing this book has been an honour as it brings together diverse authors researching on different streams of the field. The book collates essential materials contributed by veterans in the area which can be utilized by students and researchers alike.

A global perspective regarding the complications of diabetic foot is presented in this profound book. Over the last few years, diabetes mellitus has increasingly garnered attention as a global epidemic. The effect of diabetes is promptly apparent in its occurrence in foot complexities across cultures and continents. In this innovative compilation of works by international experts, the explosion of foot disease in locations which must readily deal with both mobilizing medical expertise and shaping public policy to best prevent and treat these severe complications have been reviewed. In other locations of the world where diabetic foot complexities have been sadly much prevalent, diagnostic testing and improved treatments have been developed in response. A large portion of this book has been dedicated to probing the latest advancements in basic and clinical research on the diabetic foot. This book provides an extensive understanding of the pathophysiologic process of diabetic foot complications, which will aid in reducing their distressing impact on a global scale.

Each chapter is a sole-standing publication that reflects each author's interpretation. Thus, the book displays a multi-faceted picture of our current understanding of application, resources and aspects of the field. I would like to thank the contributors of this book and my family for their endless support.

Editor

# Contents

---

	<b>Preface</b>	<b>VII</b>
	<b>Part 1 Global Impact of Diabetic Foot Complications</b>	<b>1</b>
Chapter 1	<b>Reducing Diabetic Foot Problems and Limb Amputation: An Experience from India</b> Sharad Pendsey	<b>3</b>
Chapter 2	<b>Possible Diabetic-Foot Complications in Sub-Saharan Africa</b> Ezera Agwu, Ephraim O. Dafiewhare and Peter E. Ekanem	<b>13</b>
	<b>Part 2 Diagnostic Considerations in Diabetic Foot Complications</b>	<b>25</b>
Chapter 3	<b>Screening of Foot Inflammation in Diabetic Patients by Non-Invasive Imaging Modalities</b> Takashi Nagase, Hiromi Sanada, Makoto Oe, Kimie Takehara, Kaoru Nishide and Takashi Kadowaki	<b>27</b>
Chapter 4	<b>Wound Measurement in Diabetic Foot Ulceration</b> Julia Shaw and Patrick M. Bell	<b>47</b>
Chapter 5	<b>Wound Fluid Diagnostics in Diabetic Foot Ulcers</b> Markus Löffler, Michael Schmohl, Nicole Schneiderhan-Marra and Stefan Beckert	<b>59</b>
Chapter 6	<b>The Temporary Orthesio-Therapy for Diabetic Foot</b> Richard Florence	<b>83</b>
Chapter 7	<b>The Biomechanics of the Diabetic Foot</b> Dennis Shavelson	<b>103</b>
Chapter 8	<b>A Protocol for Primary Podogeriatric Assessment for Older Patients with Diabetes Mellitus</b> Arthur E. Helfand	<b>129</b>

<b>Part 3</b>	<b>Treatment of Diabetic Foot Ulcerations</b>	<b>153</b>
Chapter 9	<b>The Pathogenesis of the Diabetic Foot Ulcer: Prevention and Management</b> F. Aguilar Rebolledo, J. M. Terán Soto and Jorge Escobedo de la Peña	<b>155</b>
Chapter 10	<b>Nutritional Treatment of Diabetic Foot Ulcers - A Key to Success</b> Patrizio Tatti and Annabel Barber	<b>183</b>
Chapter 11	<b>Role of Nitric Oxide in Extracellular Matrix Metabolism and Inflammation in Diabetic Wound Healing</b> Victor L. Sylvia, Audra D. Myers, Brandon M. Seifert, Eric M. Stehly, Michael A. Weathers, David D. Dean and Javier LaFontaine	<b>199</b>
Chapter 12	<b>Intralesional Human Recombinant Epidermal Growth Factor for the Treatment of Advanced Diabetic Foot Ulcer: From Proof of Concept to Confirmation of the Efficacy and Safety of the Procedure</b> Pedro A. López-Saura, Jorge Berlanga-Acosta, José I. Fernández-Montequín, Carmen Valenzuela-Silva, Odalys González-Díaz, William Savigne, Lourdes Morejon-Vega, Amaurys del Río-Martín, Luis Herrera-Martínez, Ernesto López-Mola and Boris Acevedo-Castro	<b>217</b>
Chapter 13	<b>Charcot Neuro-Osteoarthropathy</b> A.C. van Bon	<b>239</b>
Chapter 14	<b>Lactoferrin as an Adjunctive Agent in the Treatment of Bacterial Infections Associated with Diabetic Foot Ulcers</b> Maria Elisa Drago-Serrano, Mireya De la Garza and Rafael Campos-Rodríguez	<b>247</b>

Permissions

List of Contributors

## **Part 1**

# **Global Impact of Diabetic Foot Complications**





# Reducing Diabetic Foot Problems and Limb Amputation: An Experience from India

Sharad Pendsey  
*Diabetes Clinic & Research Centre*  
*"Shreenivas", Opp. Dhantoli Park*  
 Nagpur  
 India

## 1. Introduction

India has a dubious distinction of having largest number of persons with diabetes in the world. Type 2 diabetes has become the most common metabolic disorder. Its prevalence is growing more rapidly among people in the developing world, primarily due to marked demographic and socioeconomic changes in these regions. India currently leads the world with an estimated 41 million people with diabetes; this figure is predicted to increase to 66 million by 2025. The diabetes epidemic is more pronounced in urban areas in India, where prevalence rates of diabetes are roughly double than those in rural areas. Diabetic foot is one of the most devastating chronic complications of diabetes and is the leading cause of lower limb amputation.

Although population based data are not available, rough estimates indicate that in India approximately 45,000 legs are amputated every year, and the numbers are increasing each year. Almost 75 % of these amputations are carried out in neuropathic feet with secondary infection, which are potentially preventable. Certain factors like bare – foot walking, illiteracy, low socioeconomic status, late presentation by patients, ignorance about diabetic foot care among primary care physicians and belief in alternative systems of medicine contribute to this high prevalence. Lack of trained professionals in diabetes foot care in India and the profession of podiatry being non – existent compound the problem further. The novel project "Step – by – Step Improving Diabetes Foot care in the developing world" was initiated in India. The goal was to train healthcare professionals in basic foot care, improve their educational skills, and provide them hand on experience in treatment of trivial foot lesions. The aim was to encourage them to set up minimum model diabetic foot clinics where they would be able to prevent trivial foot lesions becoming catastrophe.

This carefully designed and executed project to improve diabetic foot care in the developing world turned out to be a major success. The strength of the Step by Step project was that it consisted of basic and an advanced course to be attended by the same delegates. In all, 100 teams of doctors & nurses were selected for training in diabetes foot care. The participants selected were specifically from smaller cities and towns, and had no previous training in diabetes foot care. They were offered a 2 day Basic Course in 2004 followed by a 2 day

Advanced Course in 2005. The courses were held in the 4 metros of India (New Delhi, Mumbai, Chennai, Kolkata), with 25 teams participating in each metro. Each team was given educational material, books on diabetic foot, video and CDs (patient education and education for healthcare professionals) and special diagnostic and therapeutic instruments kits. A national and international faculty of experienced educators in the field was responsible for teaching and chaired the practical sessions.

## **2. Diabetic foot Indian scenario**

Type 2 diabetes has become the most common metabolic disorder. Its prevalence is growing more rapidly among people in the developing world, primarily due to marked demographic and socioeconomic changes in these regions. India currently leads the world with an estimated 41 million people with diabetes; this figure is predicted to increase to 66 million by 2025. The diabetes epidemic is more pronounced in urban areas in India, where prevalence rates of diabetes are roughly double than those in rural areas. (Mohan et al., 2007).

Diabetic foot is one of the most devastating chronic complications of diabetes and is the leading cause of lower limb amputation. (Boulton et al., 2005). It is often an inching, painless surprise that holds in its dark portals a soon rising flood of complications. It is a quiet dread of disability, long stretches of hospitalization, mounting impossible expenses with the ever dangling end result of an amputated limb. The phantom limb plays its own cruel joke on the already demoralized psyche. The diabetic foot, no wonder is one of the most feared complications of diabetes.

From the 41 million population of diabetic persons in India, 90% do not even see a specialist in their life time. Majority are treated either by primary care physicians or by practitioners of alternative medicine while some buy and follow treatment exclusively on the basis of advertisements published in lay press which assure guaranteed success in cure for diabetes. (Pendsey, 2010).

As the number of diabetics worldwide increase, there will be more diabetic foot problems. The escalating number of foot problems is due not only to the increasing diabetic population but to the fact that they are now living long enough to develop foot complications. Many healthcare professionals involved in managing persons with diabetes show little interest in diabetic foot problems, furthermore the diabetic foot is frequently regarded with hopelessness as if progression down the road to major amputation is inevitable once ulceration has developed. (Pendsey, 2010).

Although population based data are not available, rough estimates indicate that in India approximately 45,000 legs are amputated every year, and the numbers are increasing each year. Almost 75 % of these amputations are carried out in neuropathic feet with secondary infection, which are potentially preventable. In India clinical profile of diabetic foot differs because of several factors such as practice of walking barefoot, wearing inappropriate footwear like Hawaiian slippers, illiteracy, low socioeconomic status, late presentation by patients, faith in alternative system of medicine and lack of awareness among primary care physicians about diabetic foot and its consequences. (Pendsey, 2010).

Lack of trained professionals in diabetes foot care in India and the profession of podiatry being non-existent compound the problem further. (Pendsey,2007).

In India neuropathic lesions are dominant and account for 80% of foot ulcers and the remaining 20% being neuroischaemic. Among the causative factors, extrinsic factors like injuries due to sharp objects ,inappropriate footwear and thermal injuries account for 70% of neuropathic foot ulcerations. Intrinsic factors which are indicators of long standing polyneuropathy such as foot deformities, limited joint mobility, bony prominences and neuroarthropathy account for remaining 30% of neuropathic foot ulcerations.

Peripheral vascular disease (PVD) has been reported to be low among Asians (Pendsey 1998) ranging between 3 – 6% as against 25 – 45% in Western world. (Marinelli et al.,1979; Migdalis et al., 1992; Walters et al., 1992). The prevalence of PVD increases with advancing age and is 3.2% below 50 years of age and rises to 55% in those above 80 years of age. Similarly it also increases with increased duration of diabetes, 15% at 10 years and 45% after 40 years (Janka,et al., 1980). In India the number of diabetic patients above the age of 80 years or with the duration of diabetes of more than 30 years is extremely low, thus explaining the low prevalence of PVD in Indian diabetics. (Pendsey 1998).



Fig. 1. Severely infected foot



Severely infected foot is the hallmark of Indian diabetic foot. It is not uncommon to see a patient with foul smelling, oedematous and severely infected foot with moribund general condition. Such patients have life threatening infection and therefore invariably require primary limb amputation. (Pendsey 2010).

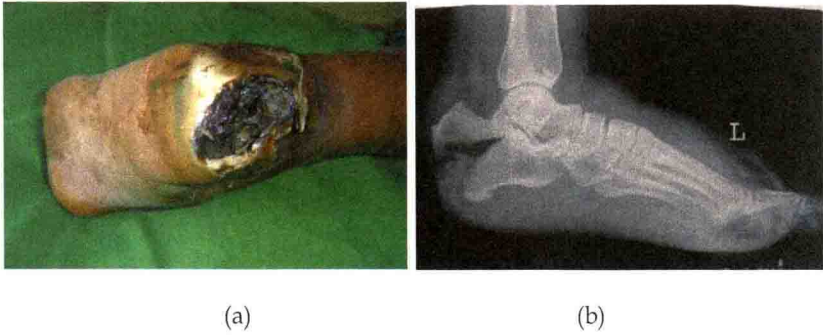


Fig. 2. (a). Infected heel with necrosis of the soft tissue (b). Radiograph showing osteomyelitis of calcaneum, soft tissue swelling with gas shadow in the area of forefoot.

Certain atypical presentations are seen because of socio economic and cultural factors prevalent in India. Patients with neuropathy and consequent loss of protective sensations, who sleep on the floor are invariably bitten by house rats who nibble toes creating deep foot ulcerations. Patients notice the ulcers on waking up to find blood stained bed linen, in the morning. Patients notice the ulcers on waking up to find blood stained bed linen, in the morning.



Fig. 3. Showing ulcers on second and fifth toes due to rat bite

Patients with neuropathy who visit religious places (temples) during summer months when the day temperature ranges between 43 and 47 degrees Celsius, develop severe thermal injuries. They are compelled to walk barefoot as religion does not permit wearing shoes.

Indians are known for sitting cross legged for long hours at work and during worship. Repeated and prolonged pressure over lateral malleolar areas lead to formation of bursae. Such bursae over lateral malleoli are dark and hypertrophied but are usually harmless in non neuropathic individuals. In diabetics with neuropathy, these bursae get ulcerated and often secondarily infected, creating a surgical emergency. Indian women wear metal (silver being commonest) toe rings in one or more toes of both feet, which is part of tradition. In neuropathic feet with deformities of toes, these toe rings often cause strangulation in presence of swelling of the feet. In tropical climate due to excessive sweating, fungal infection quickly sets-in, in web spaces. In diabetics with neuropathy these macerated ulceration often gets secondarily infected and find their way, quickly, to deep plantar compartments creating a limb threatening situation. (Pendsey 2010).



Fig. 4. Showing thermal injury on the plantar area of right foot.

### 3. Step by step diabetic foot care project in India

In view of the magnitude of the problem of diabetic foot, it was felt that there was an urgent need for training of doctors and nurses in diabetic foot care, in the Indian sub continent. Trivial foot lesions precede 85 % of leg amputations. Training of doctors and nurses will help them to take care of such trivial lesions and prevent the majority of leg amputations and simultaneously offer preventive foot care and advice about proper footwear.

The Step – by – Step project was hence conceived with a common objective of improving diabetes foot care in the developing world. (Bakker,et al.,2006; Pendsey, 2007a, 2010b). The Project Committee consisted of SharadPendsey, India (Chairman), Karel Bakker, The Netherlands, Althea Foster, United Kingdom, Zulfiqarali G. Abbas, Tanzania, Vijay Vishwanathan, India. It had academic support from International Diabetes Federation (IDF) , Diabetic Foot Society of India (DfSI), Muhimbili University college of health sciences (MUHS) and International working group on Diabetic Foot (IWGDF) . The project received financial grant from World Diabetes Foundation (WDF).

### 3.1 Goals

To create more awareness of diabetic foot problems

To provide sustainable training of health care professionals in the management of diabetic foot

To facilitate the cascading of information from health care professionals who have undergone training to other health care professionals and thus export expertise

To reduce the risk of lower limb complications in people with diabetes

To empower people with diabetes to care for their feet better, detect problems earlier and seek timely help when problems arise.

### 3.2 Methods

Special foot care education materials, both visual and audio-visual, were designed specifically for people with diabetes in developing countries. Foot care education materials, visual and audio-visual, were also designed for healthcare professionals working with people with diabetes in developing countries. Kits of diagnostic instruments (10gm monofilament, tuning fork, etc) were distributed to participants.

Therapeutic instruments' kits (Bard Parker handle with surgical blades, nail clipper, nail files, artery and tooth forceps, scoop, probe, and scissors) were also distributed to the participants.

### 3.3 Project at a glance

In all, 100 teams of doctors & nurses – India (94), Bangladesh (3), Sri Lanka (2), Nepal (1) were selected for training in diabetes foot care. The participants selected were specifically from smaller cities and towns, and had no previous training in diabetes foot care. They were offered a 2 day Basic Course in 2004 followed by a 2 day Advanced Course in 2005. The courses were held in the 4 metros of India (New Delhi, Mumbai, Chennai, Kolkata), with 25 teams participating in each metro. Each team was given educational material, books on diabetic foot, video and CDs (patient education and education for healthcare professionals) and special diagnostic and therapeutic instruments kits (Pendsey 2007).

A national and international faculty of experienced educators in the field was responsible for teaching and chaired the practical sessions.



### 3.4 Basic course

In this 2 – day practical training programme, according to a step – by – step approach, participants were taught to take a history, perform physical examination, screen for neuropathy and ischaemia, and classify and stage the foot. Having identified feet at risk, they were taught to organize appropriate foot care education and take timely action in cases of ulceration or advanced foot problems. Referral pathways were discussed and adapted to local circumstances. The training sessions for the basic course were designed to be interactive and informal with practical workshops. The formal lecturing was kept to a minimum. Participants were expected to educate their patients and cascade their acquired knowledge and skills to colleagues in their regions in order to create a spin – off effect and perpetuate and sustain achievements of the project.

To practice the techniques for debridement and cutting undermined edges of ulcers, the participants were provided with sweet limes as ‘guinea pigs’ to imitate diabetic feet. The delegates were taught some quite elaborate procedures with the help of these sweet limes – trimming calluses, probing ulcers and cutting out undermined edges using a forceps.

All participants had been requested not to cut their nails for one month prior to the training, so that they could practice nail cutting on each other using nail clipper provided by the project. This particular session worked as a great icebreaker and helped develop a friendly and collaborative atmosphere (Bakker et al., 2006).

Patients with diabetic foot problems were presented and the faculty discussed them and demonstrated the practical skills of callus removal and nail trimming. Appropriate educational material designed for doctors, nurses and in particular for people with diabetes in developing countries, was discussed. In view of the many different languages and dialects that exist in the Indian subcontinent and considering the levels of literacy, a special emphasis on easy to understand audiovisual materials and pictures were given.

In the last session, delegates were divided up into smaller discussion groups and brainstormed ideas and plans for implementing the Step – by – Step Project. Then each group reported back to the whole group. Delegates were thus equipped to educate and examine patients, to record what they find and what action they take, to use the written material to improve their knowledge of the diabetic foot, and to gradually build their own diabetic foot programme. The delegates left the basic course, well equipped, to start a minimum model diabetic foot clinic in their respective regions. (Bakker et al., 2006; Pendsey, 2007)

### 3.5 Advanced course

As a prerequisite for participation in the basic course, attendees agreed to attend an advanced course within one year. At the advanced course, they were given a specially prepared patient education video and another video for training health care professionals in their regions, thus spreading awareness about diabetic foot disease and its prevention and management.

Advanced subjects – such as the management of vascular disease, biomechanics, neuropathic osteoarthropathy (Charcot Foot), imaging modalities of the diabetic foot, indications for amputations, newer treatments and effective techniques of education – were

taught. An important part of the advanced course was also reporting of the achievements in the first year. Delegates presented their activities as posters. It was gratifying to see how the teams were working in their respective centers. The majority had started practicing what they had learnt, e.g. educational activities, screening for high risk feet, use of a stepwise algorithm to analyse and investigate diabetic foot cases and management of trivial lesions (callus removal, nail trimming, deroofting of bullae, etc). Most posters were very good and showed high levels of effort and interest amongst the participants. All teams submitted cases for presentation and five were selected to make oral presentation. The cases were discussed in detail by the faculty with active participation by the delegates. To enhance participation, a quiz on foot care was also arranged. Paramedics were encouraged to show their skills on preventive foot care. They actually worked on patients removing calluses, cutting difficult nails, dressing wounds etc. The participation in this activity was spontaneous and all paramedics participated. From the way they did the job in the presence of a large number of people and in front of a live camera, it was quite clear that the practical skills they had learned during the basic course had been effectively used and frequently applied. All faculty members appreciated the dexterity and confidence shown by the paramedics. In summary, the attending delegates were adequately trained in preventative diabetic foot care. The delegates scored significantly higher on a questionnaire on foot care knowledge at the end of each course than they had done at the beginning.

Characteristics	1 <sup>st</sup> year	2 <sup>nd</sup> year	Increase (%)
Patients screened for high risk feet	45,000	82,761	83.92
Patients who received foot care education	45,000	79,399	76.44
Patients with high risk feet	15,000	38,082	153.88
Patients receiving treatment for trivial foot lesions	4500	9716	115.91
Referral to tertiary Centre	350	388	10.85
Limbs salvaged	900	1943	115.88

Table 1. Showing the overview of the work by the delegates.

3.6 Impact

100 foot care clinics (minimum model) were started. It is anticipated that they will cascade information to large numbers of persons with diabetes, and also to other healthcare professionals, including paramedics, physicians, educators, healthcare policymakers and lay people. The formal training is expected to reduce the amputation rate among these patients



by about 50% .There will be a long-term network of all the participants to ensure percolation of knowledge throughout the country.

### 3.7 Results

The data was collected by a questionnaire sent to all participating delegates and results of 1<sup>st</sup> year after the basic course and 2<sup>nd</sup> year after the advanced course were evaluated 85 teams, from India, responded to the questionnaire for both years. From the overview of the work carried out by the delegates it was apparent that there was a significant increase in every activity they conducted in the second year, over the first year. In the absence of any formal training in diabetes foot care, about 20% of patients with trivial foot lesions would be expected to have lower extremity amputation.( Muller et al., 2002; Ramsey et al., 1999;).

Thus, in the 1<sup>st</sup> year, at least 900 lower limbs and in the 2<sup>nd</sup> year 1943 limbs were salvaged. (Pendsey 2007).

## 4. Conclusion

This carefully designed and executed project to improve diabetic foot care in the developing world turned out to be a major success. The strength of the Step by Step programme is that the project consists of a two-year set up: a basic and an advanced course to be attended by the same delegates. The prerequisite to participate in the first course was to agree to follow the second course. The attendees were supplied with a free full set of clinic equipment. Combined with the education and teaching materials, and the acquired knowledge, the participants could immediately start to improve the local foot care management. The lively and interactive exchange of thoughts through the presentation of case reports by the delegates made them more alert to common pitfalls. The delegates realised the possibility of improving management by means of rather simple and affordable care, including education of patients. Another strength of the project was the interaction of both doctors and nurses or paramedics in the teams. The faculty felt that the enthusiasm of the participants to do even better in the future was amazing and many showed commitment to roll out the learning to others in the region. The clinical profile of diabetes differs across the world on account of differences in social, economic and cultural factors. The burden of diabetes as well as its complications like the diabetic foot increasing. Every small step taken to improve diabetic foot care will be a step in right direction in preventing this dreaded complication of diabetic foot.

## 5. Acknowledgement

The author acknowledges World Diabetes Foundation for providing Financial Grant for the Step-by-Step Foot care project.

## 6. References

Bakker, K.; Abbas, ZG. & Pendsey, SP. (2006). Step by step, improving diabetic foot care in the developing world. A pilot study for India, Bangladesh, Sri Lanka and Tanzania. *Pract Diab Int*, 23:365-369.