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Limb Preservation JOURNAL

Global Challenges In Limb Preservation

Starting A Limb Preservation Clinic

The Role Of Peer Support In The Amputation Journey

Charcot Neuroarthropathy: Salvage Or Amputation?

Redesigning Ankle-brachial Index Calculation For Better Wound Care

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FROM THE EDITOR IN-CHIEF

Dear colleagues,

It is my pleasure to share with you the seventh volume of *Limb Preservation Journal*, which arrives at a moment of genuine vitality in our field. The contributions assembled here span six continents, a dozen clinical disciplines and the full spectrum, from bench-level pathophysiology to patient narrative. Reading them together, several themes emerge that are worth naming.

The most ambitious argument in this issue belongs to Badr and Maguire, whose comparative analysis of global health system models frames the amputation rate as a structural verdict on health system performance. Their epidemiological paradox is worth sitting with - the United States and resource-constrained 'out-of-pocket' systems produce the world's highest limb loss rates, driven by fragmentation and the absence of infrastructure respectively, while Beveridge, Bismarck and National Health Insurance models consistently achieve lower rates despite comparable metabolic burdens. For a Canadian audience, the provincial variation documented in recent literature is a reminder that universal financing is necessary but not sufficient. What translates health system coverage into preserved limbs is the distribution of vascular specialists, structured referral pathways and functioning multidisciplinary foot teams.

Building and sustaining those teams is the practical preoccupation of several other contributions. Manji's roundtable distills the "irreducible minimum" for a limb preservation clinic to podiatric and vascular surgery working in concert, with honest accounts of how long that takes to establish and how vulnerable the remission surveillance gap leaves patients who have successfully healed. Theodorakopoulos and Armstrong offer the WIfI classification, not merely as a staging tool, but as a clinical mindset: a framework for setting urgency and triggering escalation before the window for intervention closes. Krehbiel and colleagues make the case for the three-minute diabetic foot exam as a population-level prevention strategy, one designed for the primary care clinician and community health worker who will encounter the at-risk patient years before the limb preservation specialist does.

Decision-making at the surgical crossroads is addressed with real depth. Strauss and colleagues present a three-score system for Charcot neuroarthropathy that integrates wound severity with patient wellness and patient goals, correctly insisting that the decision about salvage versus amputation cannot be reduced to the wound alone. The lymphedema case reported by Estfanous reaches a similar conclusion from a different direction: in a patient considering amputation after years of

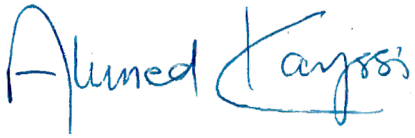
treatment failure, the decisive intervention was not a clinical technique, but the restoration of hope and therapeutic engagement through shared decision-making. Both articles argue, in effect, that the patient is always a variable in the clinical equation.

Two further contributions address the diagnostic challenge that underlies much limb loss: missed peripheral arterial disease. Beaumier's angiosome-based ABI work demonstrates that 40% of standard ABI calculations in her cohort did not represent the artery irrigating the wound bed, a finding with direct implications for clinical practice. Njokweni's conceptual amputation prevention protocol from a public regional hospital in South Africa addresses the same problem from a system design perspective, arguing that the gap between evidence and outcomes in resource-limited settings is primarily a coordination failure rather than a knowledge failure.

The remaining articles expand the frame. The obesity and Diabetic Foot Ulcer review by Brocklehurst and colleagues makes the case for treating excess adiposity as a modifiable upstream determinant of foot disease rather than a background variable, with important caveats about the nutritional risks of pharmacological weight loss in patients with active wounds. The persuasive email intervention study by Nickel and colleagues explores how digital technology can extend prevention into patients' daily lives. The Limbloss Connection article by Polese, Gray, and Ramhacklam is a direct account of what the clinical pathway looks like from the other side of the operating table, and a practical argument for peer support as a routine component of amputation care. The two-island Caribbean case report by McConnie and Budhoo is a reminder that multidisciplinary care is achievable across resource limitations and international borders when the team is committed. And the D-Foot International overview by Nair, Gangji and Abbas traces 22 years of global education and advocacy work, with both the impact data and the honest acknowledgement of what remains unfinished.

What this issue adds up to is a sustained argument that most preventable amputations are still preventable, and that the obstacles are organizational and structural as much as they are clinical. We are very grateful to the authors, reviewers, and readers who make this journal part of that argument.

Sincerely yours,



Ahmed Kayssi, MD MSc MPH CWSP FRCSC FACS

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NEWS FROM OUR PARTNERS

Wounds Canada Launches the *Patient Bill of Rights and Responsibilities in Wound Prevention and Care (PBoRR-WPC)*

Wounds Canada and its partners have officially launched the *Patient Bill of Rights and Responsibilities in Wound Prevention and Care (PBoRR-WPC)*, the purpose of which is to empower individuals with lived experience, support health-care providers in delivering high-quality wound care, advance advocacy efforts and guide equitable, person-centred care practices.

The BoR was conceptualized and led by Dr. Idevania Costa RN NSWOC PhD, Associate Professor in the School of Nursing at Lakehead University in Thunder Bay ON, and co-founder of the *Our Voices, Our Stories* initiative. This work was financially supported by the Social Sciences and Humanities Research Council of Canada (SSHRC), with additional in-kind contributions from Wounds Canada. The PboRR-WPC reflects the lived experiences and direct narratives of patients and care partners, drawing on real patient and caregiver interviews. It identifies 12 core rights that individuals deserve across the continuum of care, paired with corresponding responsibilities to support active participation and advocacy.

The full document will be published as a Supplement to *Wound Care Canada* (Vol. 24 No. 1) and will be available on the Wounds Canada website (www.woundscanada.ca) in June.

Find out more at: Patient Bill of Rights and Responsibilities - Wounds Canada

Upcoming Regional And National Events

Western Region Hands-On Skills Lab: June 16, 2026: Wounds Canada is hosting a hands-on, interprofessional skills lab *Best Practice Approach to Skin Health and Wound Management: Knowledge and Skills* (A100NWS) in Edmonton, Alberta. This full-day learning experience reinforces the knowledge from the A100MNN prerequisite course *Best Practice Approach to Skin Health and Wound Management: Knowledge* program and includes a follow-up live webinar with expert faculty. The practical lab provides opportunities to practice wound assessment, measurement, cleansing, identifying infection and dressing selection as well as practice conservative sharp wound debridement while applying best practices to real-world case scenarios. Upon completion, participants will receive a Digital Certificate of Completion from the Wounds Canada Institute and a Digital Micro-Credential Badge from Nipissing University.

Regional Conference Edmonton: June 17, 2026: Wounds Canada is also hosting an exciting regional conference at Concordia University in Edmonton, Alberta. The *Western Region Skin Health and Wound Care Conference* will include a full day of both academic and sponsored sessions and a table-top exhibit area to showcase innovative wound care products and resources. More info on both these regional events can be found at: Western Region Skin Health and Wound Care Skills Lab and Conference - Wounds Canada

Wounds Canada National Hybrid Conference 2026: Planning for the Wounds Canada National Hybrid conference is well underway. The event will welcome professionals from across Canada from October 22–24, 2026, in Niagara Falls, ON. The event is an opportunity to network with health-care experts and other professionals passionate about wound care. More info can be found at: Wounds Canada 2026

Ongoing Awareness Campaigns: Wounds Canada continues to spread awareness on wound care and limb preservation using our vast network and in-depth knowledge to educate Canadians on crucial topics. Follow our social media page for more info check out our campaigns here: Awareness Campaigns - Wounds Canada

CariWN Builds Momentum

The Caribbean Wounds Network (CariWN), launched in 2024, continues to build momentum in addressing the region's wound care crisis.

Like Wounds Canada, CariWN remains grounded in four key pillars—Education, Advocacy, Research and Implementation—which guide our mission to improve wound management and limb preservation outcomes throughout the Caribbean.

In 2025, CariWN expanded its regional impact through several strategic initiatives. These included the launch of a webinar series designed to enhance access to ongoing training and professional development for health-care providers across the region.

Recent webinars have featured:

- Dr. Maria Goddard: Mastering Burn Care: From Triage to Reconstruction
- Dr. Adrian Wyllie: Wound Care Essentials For The Post-Acute Clinician
- Dr. Esther Daniel: Foundations - Why Moist Wound Healing Still Matters.

Our ongoing webinar series continues to serve as a key platform for education, knowledge sharing and professional engagement. Our webinars are open to participants from anywhere in the world, fostering a truly global community of practice.

In addition, we partnered with the Horacio Oduber Hospital in Aruba to deliver the 7th Island Wound Care Symposium virtually, enabling broader participation from health-care professionals across the region and beyond, who may otherwise have faced travel limitations or restrictions. This initiative reflects our commitment to reducing barriers to education and fostering greater regional collaboration.

The Aruba conference was well-received. More than 100 registrants who otherwise might not have experienced this world class event were able to participate virtually.

If you are interested in speaking at a CariWN webinar or conference, please contact: info@cariwn.org.

CariWN also continues to strengthen its partnerships and outreach efforts. As part of our broader Caribbean engagement strategy, we are actively connecting with individual islands and nations to explore opportunities for training, continuing education and capacity-building initiatives. We are also seeking to engage Ministries of Health across the region to support policy development, professional standards and improved patient care. In parallel, we are engaging local universities to assess opportunities for academic collaboration, research and curriculum development.

Looking ahead, we are pleased to share that the University of the West Indies, Faculty of Medical Sciences, has expressed interest in co-hosting our 2026 CariWN Conference at the UWI Mona Campus in Jamaica. We are currently working closely with their team to finalize dates and logistics. This collaboration represents a strong foundation for deeper engagement within Jamaica, supported by local volunteers who have committed to assisting with on-the-ground coordination.

Building on our regional presence, CariWN will also continue supporting key partner events, including ongoing collaboration with stakeholders in Aruba and across the Caribbean. Our efforts remain focused on expanding access to evidence-based resources, strengthening professional networks and advancing advocacy initiatives that influence policy and improve standards of care.

With wound care costs in the Caribbean estimated at approximately $7 billion annually, the need for coordinated, strategic action remains urgent. CariWN's emphasis on research will help develop a stronger understanding of wound care within the Caribbean context, while our implementation pillar ensures that best practices and next practices are effectively translated into clinical settings.

As a member of the Limb Preservation Alliance and in collaboration with organizations such as Wounds Canada, CariWN is well-positioned to drive meaningful, sustainable improvements in wound care and limb preservation across the region.

CariWN continues to serve as a unifying community and network —engaging health-care professionals, educators, institutions, and the Caribbean diaspora—in a shared mission to advance wound care, reduce preventable amputations and improve patient outcomes throughout the Caribbean.

CariWN membership is free. Individuals are welcome to join as corresponding members to gain access to our webinars and conferences. We invite all interested individuals to become part of our growing network. We welcome you to collaborate with us, support our community and contribute to advancing wound care across the region.

To join or for more information, email: info@cariwn.org or visit: www.cariwn.org

100 Years Of Advancing Limb Preservation Through Collaboration And Innovation

Limb preservation remains one of the most important and complex challenges in modern health care. As rates of diabetes, peripheral vascular disease and chronic wounds continue to rise, preventing lower extremity complications requires coordinated care across multiple disciplines. Podiatrists play a central role in this effort, contributing expertise in biomechanics, wound management, infection control and surgical intervention.

The Canadian Podiatric Medical Association (CPMA) continues to support this work by strengthening interdisciplinary collaboration, advancing clinical education and promoting innovation in lower extremity care across Canada.

Strengthening Interdisciplinary Partnerships: Effective limb preservation depends on strong collaboration between health-care professionals involved in wound care, diabetes management, vascular medicine and rehabilitation.
Over the past year, CPMA has continued to build relationships with organizations committed to improving outcomes for patients at risk of limb loss.

In 2025, CPMA participated in the Wounds Canada conference and contributed to the National Wound Community Think Tank, ensuring that podiatric expertise remains represented in national conversations surrounding wound care strategy and best practices. These forums provide valuable opportunities to share clinical perspectives, identify gaps in care, and strengthen coordinated approaches to limb preservation.

CPMA also expanded its engagement with the Canadian Association of Foot Care Nurses, opening new opportunities for collaborative education and knowledge exchange. Nurses and podiatrists frequently work together in community and clinical settings, and strengthening these partnerships helps improve early detection, prevention and management of foot complications.

Advancing Clinical Education: Education remains central to CPMA's mission. Throughout 2025, the Association delivered a series of educational webinars addressing clinical and system-level issues relevant to podiatric practice and limb preservation.

Topics included innovations in wound-healing technologies, advances in antimicrobial therapies, diagnostic developments for onychomycosis and outcomes associated with transmetatarsal amputation in diabetic limb salvage. Additional programs explored broader health-care challenges, including access to care and health equity.

By providing accessible virtual education, CPMA helps ensure that clinicians across Canada can remain current with evolving evidence and emerging technologies in lower extremity care.

Encouraging Innovation and Research: Innovation continues to shape the future of limb preservation. New diagnostic tools, wound healing technologies and treatment approaches

are expanding the possibilities for preventing amputations and improving patient outcomes.

CPMA remains engaged with clinical researchers and industry partners to explore advances in wound care and lower-extremity diagnostics. While research funding in Canada remains highly competitive, the Association continues to seek opportunities to support interdisciplinary research initiatives that address complex challenges in limb preservation.

Supporting the Future Workforce: The sustainability of limb preservation efforts depends on developing the next generation of podiatric physicians. CPMA continues to engage Canadian podiatry students studying internationally through mentorship initiatives, scholarship programs and professional guidance. These efforts help strengthen early connections between students and the Canadian podiatric community while supporting the development of future clinicians who will contribute to multidisciplinary limb preservation teams.

Looking Ahead: As the Canadian Podiatric Medical Association celebrates its 100th anniversary in 2026, the organization remains focused on advancing podiatric medicine and strengthening its role within interdisciplinary health care. Through continued collaboration, education and innovation, CPMA is committed to supporting clinicians in preventing amputations and improving the quality of life for patients at risk of limb loss.

For more information on CPMA's initiatives, visit podiatrycanada.org

American Limb Preservation Society

DFCon 2026 To Be Held In October

DFCon 2026, the Annual Conference of the American Limb Preservation Society will be held on October 22-24, 2026, in Anaheim, California.
This year's conference will focus on:

- Leadership in Discovery: Be at the forefront of groundbreaking therapies and technologies.
- Collaborative Networking: Connect and collaborate with global experts, enhancing professional growth and innovative practices.
- Expert Insights: Learn from leading speakers and stay updated on the latest research.

To register, or for more information, visit: limbpreservationsociety.org/dfcon

Save The Date: Diabetic Foot Update 2026

DFUpdate 2026: Leading PAD Care is scheduled for December 5-6 in San Antonio, Texas.
Led by ALPS, this year's event tackles key challenges and innovations in PAD through expert discussions and collaboration. Highlights include:

- A Hub for Innovation: Engage in interactive workshops, expert debates, and evidence-based updates to improve patient care and advance limb preservation.
- Collaborate for Better Outcomes: DFUpdate 2026 unites specialists across disciplines to drive groundbreaking solutions and enhance patient quality of life.

For more information, visit: limbpreservationsociety.org/

D-FOOT international

D-Foot International

D-Foot International is a global, non-profit association dedicated to the prevention of diabetes-related foot complications and lower-limb amputations. The work of D-Foot International is featured in an article in this issue (See pgs. 104-109).

For more information, visit: https://d-foot.org

CASE REPORT

Limb Preservation In Advanced Primary Lower-Limb Lymphedema: A Case Report Highlighting Conservative Physical Therapy–Led Management

Kerelous George Estfanous CLT PT

Abstract: Advanced chronic lower-limb lymphedema can lead to significant physical morbidity, skin complications, recurrent wounds and profound psychological distress. Conservative limb preservation strategies remain underrepresented in the literature, particularly from the perspective of physical therapy-led interventions. This case report describes a patient with long-standing primary lower-limb lymphedema who presented with advanced limb enlargement, chronic skin changes and functional limitation. A structured conservative limb preservation approach was implemented and limb preservation was achieved. This case highlights the critical role of conservative physical therapy–based interventions in limb preservation for advanced chronic lymphedema.

Key words: *lower-limb lymphedema, limb preservation, physical therapy, lymph drainage, shared decision-making*

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DOI: 10.56885/124450ijemdg

Chronic lower-limb lymphedema is a progressive condition associated with significant physical morbidity, skin complications, recurrent wounds and functional impairment.[1,2] In advanced stages, long-standing lymphatic dysfunction may result in severe limb enlargement, tissue fibrosis and compromised skin integrity, increasing the risk of infection and limb loss, and negatively affecting quality of life.[3,4]

While surgical interventions may be considered in selected cases, conservative management remains the cornerstone of lymphedema care. Complete decongestive therapy (CDT), incorporating manual lymph drainage, compression therapy, skin care and exercise, has demonstrated effectiveness in reducing limb volume and preventing disease progression.[3] However, in cases with advanced chronic disease, repeated treatment failure and prolonged symptom burden may lead to therapeutic exhaustion and significant psychological distress.

In extreme circumstances, patients may consider limb amputation as a perceived solution to ongoing suffering, despite the absence of acute life-threatening indications. Reports focusing on conservative limb preservation strategies at this critical decision point remain limited in the literature, particularly those highlighting the role of physical therapy–led interventions.

This case report describes the successful limb preservation of a patient with advanced primary lower-limb lymphedema who was considering amputation prior to referral. The report emphasizes clinical decision-making, structured conservative intervention and long-term management planning aimed at restoring function, stabilizing tissue condition and re-engaging the patient in care.

Case Presentation

A patient with long-standing primary lower-limb lymphedema was referred for evaluation and management following years of progressive disease. The condition was characterized by marked limb enlargement, chronic skin changes and areas of recurrent skin breakdown. Functional mobility was significantly limited, and the physical burden of the condition was compounded by persistent discomfort and reduced independence in daily activities (Figure 1).

Over time, the cumulative impact of prolonged disease progression and prior unsuccessful management attempts resulted in significant psychological distress. At the time of presentation, the patient expressed a desire to pursue lower-limb amputation as a means of alleviating ongoing symptoms and improving overall quality of life.

Clinical examination revealed advanced tissue congestion, altered skin texture consistent with chronic lymphatic insufficiency, and compromised skin integrity in the distal portion of the limb. No acute infection or immediate surgical indication was identified at the time of assessment. Given the absence of urgent surgical necessity, a conservative limb preservation approach was proposed and discussed in detail with the patient.

Following informed consent, a structured conservative treatment plan was initiated with the goal of limb preservation, symptom reduction and establishment of a sustainable long-term management strategy.

Intervention

A conservative limb preservation strategy was initiated, based on the principles of complete decongestive therapy (CDT) and tailored to the advanced stage of the patient's condition. Treatment planning focused on gradual tissue decongestion, protection of skin integrity and restoration of functional tolerance, while addressing the patient's physical and psychological fatigue from previous unsuccessful interventions (Figure 2).

The initial phase of treatment emphasized gentle manual lymph drainage techniques adapted for chronic tissue changes, aiming to stimulate proximal lymphatic pathways and reduce distal congestion. Compression therapy was introduced progressively, with careful consideration of tissue tolerance, limb contour and skin condition. Short-stretch compression systems were utilized to support volume reduction while minimizing discomfort and risk of further skin compromise.

Targeted skin care protocols were implemented to address chronic dryness, hyperkeratosis and areas of skin breakdown. Education on daily skin inspection and hygiene was incorporated early in the treatment process to reduce the risk of infection and enhance patient engagement. Therapeutic exercises were prescribed to promote muscle pump activity and improve functional mobility within the patient's tolerance limits.

Treatment frequency and intensity were adjusted based on ongoing clinical assessment, tissue response and patient feedback. As initial improvements were observed, the intervention plan evolved to include transition strategies toward long-term self-management. A structured maintenance program was developed, incorporating ongoing compression use, periodic reassessment and reinforcement of self-care strategies to support continued improvement and limb stabilization.

Figure 1: Pre-intervention presentation of advanced primary lower-limb lymphedema demonstrating severe limb enlargement, chronic skin changes and distal tissue congestion.

Figure 2: Early post-intervention appearance following initiation of conservative physical therapy–led treatment, showing improved limb contour, reduced congestion and enhanced skin condition.

Throughout the intervention period, shared decision-making played a central role. The patient was actively involved in treatment planning, with regular discussions focused on realistic goals, expected outcomes and the importance of long-term adherence. This approach aimed to shift the patient's perspective from considering amputation as a solution to engaging in a sustainable limb preservation pathway.

Outcomes

Following the implementation of the conservative treatment program, clinically meaningful improvements were observed. A reduction in limb congestion and improved tissue pliability were noted during follow-up assessments. Skin condition demonstrated visible improvement, with enhanced integrity and a decrease in areas of active inflammation and breakdown.

Functionally, the patient reported reduced limb heaviness and improved tolerance for daily activities. These physical changes were accompanied by a notable improvement in psychological outlook, as the patient transitioned from therapeutic exhaustion to active participation in ongoing care.

Most importantly, limb preservation was achieved. The consideration of lower-limb amputation was deferred, and no surgical intervention was required during the observed treatment period. The patient successfully transitioned into a structured long-term management program focused on maintenance compression, continued skin surveillance and periodic clinical follow-up.

The outcomes of this case underscore the potential of individualized, conservative physical therapy–based interventions to alter the clinical trajectory of advanced chronic lymphedema, even at a stage where amputation is being considered.

In addition to the physical improvements observed, a notable change in the patient's psychological status was evident. At initial presentation, the patient demonstrated signs of therapeutic exhaustion and a loss of confidence in conservative management, which contributed to the consideration of amputation.

Following the intervention, the patient showed increased engagement, improved motivation and a renewed sense of control over the condition. This shift was supported by continuous patient education regarding disease understanding, self-management strategies and realistic expectations of treatment outcomes.

Discussion

Advanced chronic lymphedema represents a complex clinical challenge, particularly when prolonged disease progression leads to physical deterioration, recurrent skin complications and psychological distress. In such cases, patients may perceive amputation as a viable solution to alleviate suffering, despite the absence of acute surgical indications. This case highlights the importance of reassessing treatment pathways at critical decision points and reinforces the role of conservative management in limb preservation.

Complete decongestive therapy (CDT) remains the cornerstone of lymphedema management;[5] however, its application in advanced stages requires careful modification and clinical judgment. Chronic tissue changes, reduced skin tolerance[3] and patient fatigue from prior interventions necessitate an individualized and progressive approach. In this case, gradual decongestion, adaptive compression strategies and continuous reassessment were essential in achieving meaningful clinical improvement without exacerbating tissue compromise.

A notable aspect of this case is the psychological dimension of advanced lymphedema. Therapeutic exhaustion and loss of hope significantly influenced the patient's consideration of amputation. Addressing psychological burden through shared decision-making, realistic goal setting and early demonstration of clinical response played a critical role in re-engaging the patient in care. This emphasizes that limb preservation is not solely a physical outcome, but also a process that requires restoration of patient confidence and participation.[6]

The role of physical therapy in limb preservation pathways is often underrepresented in the literature, particularly in cases approaching surgical crossroads.

Key Clinical Lessons

- Advanced chronic lymphedema may lead patients to consider amputation due to prolonged physical and psychological burden.
- Conservative limb preservation strategies should be fully explored before irreversible surgical decisions are made.
- Physical therapy–led complete decongestive therapy can meaningfully alter disease trajectory, even in advanced cases.
- Addressing psychological distress and therapeutic exhaustion is essential to successful long-term management.
- Limb preservation is a dynamic process that requires individualized treatment planning and patient engagement.

This case demonstrates how physical therapy–led conservative interventions can alter the disease trajectory, stabilize tissue condition and defer or prevent unnecessary amputation. While surgical options remain important for selected patients, conservative management should be fully explored and optimized before irreversible decisions are made.

Limitations of this report include its single-case design and the absence of long-term quantitative volume measurements. Nevertheless, the clinical relevance of limb preservation, improved tissue condition and patient-centered outcomes provides meaningful insight for clinicians managing similar complex presentations. Further research is warranted to explore standardized conservative limb preservation protocols for advanced lymphedema and to better define multidisciplinary decision-making frameworks.

Conclusion

This case report illustrates that even in advanced chronic primary lower-limb lymphedema, where amputation is being considered, conservative physical therapy–based interventions can play a decisive role in limb preservation. Structured complete decongestive therapy, progressive compression strategies and long-term management planning contributed to meaningful clinical improvement and restoration of patient engagement in care.

Early recognition of psychological burden, combined with individualized conservative treatment, may prevent unnecessary amputations and support sustainable functional outcomes. This case reinforces the importance of integrating physical therapy as a central component of limb preservation pathways in complex lymphedema management.

Kerelous George Estfanous PT CLT is a Certified Lymphedema Therapist & Physical Therapist, Cairo, Egypt.

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Global Perspectives On Limb Preservation: A Comparative Analysis of Health System Models and Clinical Realities

Mohamad Badr MD WCSP and **Jeanine Maguire** PhD MPT FCPP CWS

Abstract: Limb preservation has emerged as a critical benchmark, and a suggested metric, of health-care system performance, reflecting the interplay of early detection, multidisciplinary coordination and reimbursement alignment. Despite advances in vascular and wound care, profound global disparities persist in lower-extremity amputation (LEA) rates. This comparative narrative review examines how the four dominant global health-care financing models—Beveridge, Bismarck, National Health Insurance (NHI), and Out-of-Pocket—influence access to limb salvage services and long-term clinical outcomes. Two contrasting regional paradigms anchor this analysis. The first is the Middle East and North Africa (MENA) region, which faces a dual burden: the world's highest proportional diabetes prevalence and a 1.39% annual increase in LEA incidence driven by political instability and armed conflict. Within MENA, marked heterogeneity exists. The second is the United States, which presents a contrasting picture of structural complexity: a system that achieved documented declines in major amputation rates through the early 2010s (Goodney et al., 2013) before experiencing a subsequent reversal, with current combined amputation rates approximately two to three times those of peer nations (Weaver et al., 2024). Universal drivers of limb loss identified across all systems include delayed patient presentation, socioeconomic disparities, deficient wound education and misaligned reimbursement.

Key words: *limb preservation, lower-extremity amputation, global health systems, diabetic foot, value-based care, MENA region, Egypt, universal health insurance, financing models*

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Traditionally, health-care system evaluations rely on complex, multi-layered metrics including administrative overhead, the prevalence of chronic conditions like heart disease and obesity, and broad measures of access and equity. However, this study posits a more singular, high-stakes benchmark: the amputation rate. We argue that a chronic wound—the primary precursor to most preventable amputations—is not merely a localized dermatological issue, but the physical manifestation of a systemic failure in chronic disease management. Non-traumatic amputation highlights the critical gap between preventive care and late-stage clinical failure. It serves as a finite measure that encapsulates the synergy—or lack thereof—between patient health literacy, provider education, care coordination and financial incentives.

Limb salvage outcomes are dictated by the national financial and structural architectures of a health-care system (Commonwealth Fund, 2025). The global urgency of this issue is underscored by staggering statistics: the International Diabetes Federation reports that "one limb is lost to diabetes every 30 seconds" (International Diabetes Federation, 2021), yet up to 85% of these amputations are considered preventable through timely, multidisciplinary intervention (American Diabetes Association, 2022).

Consequently, a detailed analysis of global health-care systems through the lens of amputation incidence is not only worth scrutiny but essential for future policy reform. Using amputation incidence as a benchmark, this analysis addresses both traumatic and non-traumatic limb loss, exploring how distinct regions navigate unique structural struggles.

Objectives

This analysis pursues the following research aims:

- To characterize the four primary global health system financing models (Beveridge, Bismarck, NHI and 'Out-of-Pocket') with respect to their structural, payment and amputation rate profiles.
- To examine educational disparities across systems regarding physician training in chronic wound care and amputation prevention.
- To identify the primary structural and metabolic drivers of preventable amputation across financing models, including systemic fragmentation and misaligned reimbursement.
- To analyze the intersecting structural challenges of the MENA region alongside the implications of the US transition to Value-Based Care (VBC) for global limb preservation policy.
- To advance the amputation rate as a validated primary benchmark of health system performance and a foundation for evidence-based global health equity advocacy.

Section I. Methods

This study employs a comparative narrative review methodology to evaluate how the structural and financial architecture of global health-care systems influences lower-extremity amputation (LEA) rates and limb preservation outcomes. A systematic search of peer-reviewed literature was conducted across PubMed, MEDLINE, PubMed Central and Google Scholar, supplemented by grey literature from the International Diabetes Federation, the World Health Organization, the Commonwealth Fund, the Centers for Medicare & Medicaid Services and relevant national health authorities. Search terms included combinations of: "lower extremity amputation," "limb preservation," "diabetic foot," "health-care systems," "Beveridge model," "Bismarck model," "universal health insurance Egypt," "MENA amputation," "value-based care" and "amputation prevention." Literature published from January 2000 through March 2026 was considered eligible; seminal foundational sources predating this range were included where their clinical or policy relevance warranted citation. Studies were selected based on relevance to health system financing models, amputation epidemiology, diabetic foot management, or limb salvage outcomes. Case reports were excluded. Data were synthesized thematically across five domains: health system model characteristics, metabolic burden, structural barriers to care, regional case studies (MENA and the United States) and emerging reform trajectories. No patient-level data were accessed; ethical approval was not required for this review.

Limitations And Metric Justification

The authors acknowledge that the lower-extremity amputation (LEA) rate as a cross-national health system indicator requires careful methodological interpretation. Differences in coding practices, definitions of major versus minor amputation and population-level diabetes prevalence introduce comparability constraints that have been noted in the health economics literature (Jeffcoate & van Houtum, 2004; Carinci et al., 2016). This analysis therefore, frames LEA rate not as a simple clinical output variable, but as a composite downstream indicator of systemic performance across the full cascade from chronic disease prevention through wound detection, early revascularization, infection management and multidisciplinary care coordination.

The diabetic foot ulcer—the primary precursor to the large majority of non-traumatic lower-extremity amputations—is not a dermatological event in isolation. It is the biological endpoint of a cascade of unmanaged upstream failures: peripheral neuropathy arising from chronically uncontrolled hyperglycemia; peripheral arterial disease eliminating tissue perfusion; recurrent undetected micro-trauma in the setting of absent protective sensation; and the compounding effects of nutritional insecurity, limited mobility, low health literacy, delayed care-seeking and inadequate access

to vascular and wound specialists (Armstrong et al., 2017; Hicks et al., 2023). Critically, applying a wound product to a patient with unresolved ischemia and unmanaged blood glucose does not heal the wound; the metabolic environment must be corrected concurrently. A systematic review and meta-analysis of 57 studies demonstrated that multidisciplinary teams integrating glycemic control, vascular management, infection treatment and wound care simultaneously reduced major amputation risk by 48% compared to siloed care (Santema et al., 2021). Amputation, therefore, occurs not because of wound complexity alone, but because the surrounding health system failed to intervene at each prior stage of this cascade—a failure that is structural, financial, educational and social in its origins.

The metric's legitimacy as a systems indicator is further supported by the Organization for Economic Co-operation and Development (OECD), which formally included diabetes-related LEA rates in its Health Care Quality Indicators project as early as 2006. An analysis of 26 OECD nations found that, after controlling for structural variables, systems financed by public taxation demonstrated significantly lower amputation rates than insurance-based counterparts, encouraging continued exploration of LEA rate as a primary indicator in the OECD's health system quality matrix (Carinci et al., 2016). The foundational case for amputation as a quality marker was established by Jeffcoate and van Houtum (2004) in *Diabetologia*, who documented that LEA rates reflect not disease severity alone, but the full architecture of care: access to primary care, referral speed, specialist availability and prevailing clinical practice. A health system that intercepts chronic disease early, deploys preventive screening, trains its clinicians to recognize the wound as a systemic signal and coordinates multidisciplinary care consistently produces lower amputation rates—regardless of baseline metabolic burden. The rate is the verdict.

Section II. Comparative Analysis Of Global Health Models

The efficacy of limb preservation is fundamentally tethered to the structural and financial architecture of a nation's health-care system. While the clinical goal—preventing amputation through revascularization and wound care—is universal, the delivery of that care is dictated by how a system is funded and managed. Globally, health-care systems generally align with one of four foundational models, each presenting distinct advantages and barriers for the limb-salvage patient (Wendt et al., 2009; Murray & Frenk, 2000). (See Table 1.)

Table 1: Comparative Framework of Global Healthcare Financing Models

Model Type	Funding Source	Key Strength	Primary Barrier
Beveridge (Socialized Medicine)	General Taxation	Standardized Protocols & Preventive Pathways	Wait Times for Specialist Access
Bismarck (Social Health Insurance)	Payroll Deductions (Private, Non-Profit)	Rapid Specialist Access & High Patient Choice	Administrative Complexity
National Health Insurance (NHI / Single-Payer)	Government-Run Insurance	Cost Efficiency via Single-Payer Leverage	Regional Resource Gaps
Out-of-Pocket (Low-income Nations)	Direct Patient Payment	None (No Formal Insurance Structure)	Late-Stage Presentation; No Safety Net
U.S. Mixed (Fragmented Mosaic)	Multi-Payer Fragmented (Private, Public, Self-Pay)	Innovation & Advanced Technology	Inequity, Fraud, & Misaligned Incentives

Key Strengths Primary Barrier Out-of-Pocket (high risk) U.S. Mixed (caution)

The Beveridge Model (Socialized Medicine)

Named for William Beveridge, the architect of the UK's National Health Service (NHS), this model treats health care as a public service financed through general taxation. Primary examples include the UK, Spain, New Zealand and Scandinavia. Hospitals are largely government-owned, and many clinicians are state employees. The government acts as the sole payer, allowing for centralized control over pricing and standardized clinical pathways (Anandaciva, 2023). The strength of this model lies in its high integration of care and population-wide preventive screening. However, budget-driven caps often lead to significant wait times for "elective" specialized wound clinics. In the context of limb salvage, delays in accessing specialists can turn a manageable foot ulcer into a life-altering amputation (Commonwealth Fund, 2025). Their standardized preventive care results in overall lower amputation rates (2.9–8.3 per 100K) (Gunja et al., 2024; Anandaciva, 2023).

Case Study: The UK NHS Integrated Diabetic Foot Care Pathway. The UK NHS offers one of the most instructive evidence-based case studies of the Beveridge model's capacity to systematically reduce amputation through structured pathway integration. The foundational model was established in 1981 at King's College Hospital, London, with the creation of the UK's first dedicated multidisciplinary diabetic foot clinic. Within three years, the rate of major amputations at that institution had halved (Edmonds et al., cited in Diabetes UK, 2024). Building on this evidence, the NHS subsequently embedded the multidisciplinary foot team (MDFT) within its national commissioning framework, mandating that all areas provide a NICE-compliant foot clinic with weekly appointments, no waiting list for urgent referrals and defined rapid referral pathways from primary to specialist care (NICE, 2015).

The real-world impact of this pathway architecture is documented through regional NHS peer review data. In the South West of England, a peer review program evaluating 14 NHS providers found a strong inverse correlation between the provision of 10 key diabetic foot care services and major amputation rates; sites that implemented service improvements achieved measurable reductions in major amputation incidence within two years (Paisey et al., 2018). Critically, the economic case for this investment is unambiguous: the annual NHS cost of diabetic foot ulceration and amputation in England was estimated at between £837 million and £962 million in 2014–2015, exceeding the combined cost of breast, prostate and lung cancer care, with 60% of expenditure occurring in preventable community and outpatient settings (Kerr et al., 2019). It should be noted, however, that NICE pathway compliance and diabetic foot outcomes vary considerably across NHS regions; geographic inequities in specialist access and audit compliance remain active areas of NHS quality improvement (Paisey et al., 2018).

The Bismarck Model (Social Health Insurance)

The primary examples of the Bismarck model include Germany, Japan, France and Switzerland. This model utilizes an insurance system financed jointly by employers and employees through payroll deductions. Unlike the US commercial market, these insurers are strictly non-profit and must cover all citizens. The Bismarck model typically offers high levels of patient choice and rapid access to specialists with high administrative efficiency and access to care. These factors ensure high-risk patients, like those with PAD, receive interventions before limb-threatening ischemia can occur (Gunja et al., 2024; Wendt et al., 2009; OECD, 2025).

Case Study: Germany's DRG System, Podological Care, and Amputation Trends. Germany's Bismarck system provides a particularly granular case study in how Diagnosis-Related Group (DRG) data—mandated from more than 99% of German hospitals—can be leveraged as a real-time quality surveillance instrument for amputation prevention. Among people with diabetes in Germany, major amputation rates declined significantly from 2008 to 2012, with the relative risk of major LEA comparing diabetic to non-diabetic populations decreasing at approximately 4% per year (Claessen et al., 2018). A longer-term national analysis documents

major amputations decreasing from 18.6 to 17.5 per 100,000 in men and 6.8 to 5.2 per 100,000 in women between 2015 and 2022 (Tuncer et al., 2024). A notable contributor was the concurrent expansion of statutory podological foot care (PFC) visits reimbursed through the German social health insurance system. Analysis found a significant inverse association between increasing PFC expenditure and decreasing major amputation rates (Kröger et al., 2014). Notably, German amputation rates, while on a declining trajectory, remain higher than those observed in Scandinavian Beveridge-model countries, indicating that Bismarck-model structural advantages have not yet fully converged with the lowest-performing peer nations (Tuncer et al., 2024).

National Health Insurance (NHI) Model

The NHI model—exemplified by Canada, Taiwan and South Korea—blends the private-provider flexibility of Bismarck with the single-payer efficiency of Beveridge. Health care is delivered by private-sector providers, but the bill is paid by a government-run insurance program. Universal coverage ensures basic diabetic foot care is accessible and, in preliminary work, leveraging single-payer data to target high-risk populations has shown promise for predictive survival modelling of diabetic foot complications, potentially enabling earlier intervention (Ramachandram et al., 2025); the system maintains a stable amputation rate of 5.0–7.0 per 100K across these nations.

Case Study: Taiwan and Canada—Single-Payer Leverage and Limb Preservation. Taiwan's NHI system, which covers approximately 98% of the population, provides a compelling demonstration of how single-payer data architecture enables targeted intervention. Among patients with diabetic foot disease, the amputation rate decreased significantly from 24.9% to 17.5% of cases between 2005 and 2014 (Lin et al., 2019; Chen et al., 2019). Taiwan's NHI also introduced a pay-for-performance (P4P) program linked to reduced incidence of lower-extremity amputations—an example of how a single-payer system can embed outcome-based financial mechanisms without the administrative fragmentation that undermines such programs in multi-payer environments.

Canada's NHI system presents a more complex picture—one that illustrates both the protective capacity of universal coverage and its limitations when not paired with integrated specialty care infrastructure. A national cohort study found that major amputation rates related to diabetes decreased over time, with reductions observed in Ontario, Manitoba and Saskatchewan—provinces with more developed integrated care networks (Jalayeri Nia et al., 2025). This provincial variation underscores that single-payer financing is a necessary, but not sufficient, condition for limb preservation: the distribution of vascular specialists, diabetic foot teams and structured referral pathways within a universal system determines whether coverage translates into salvaged limbs.

The Out-of-Pocket Model

In many developing nations, there is no formal state-wide insurance apparatus. Access to care is determined solely by the ability to pay at the point of service. Examples include rural regions of Africa, India and parts of South America, though within-region variation is considerable and certain sub-national contexts demonstrate markedly better outcomes than regional averages would suggest. Globally, over 1.6 billion people face extreme financial hardship due to these medical expenses (OECD, 2025). In these regions, limb preservation is frequently viewed as a luxury. Late-stage clinical presentation is the norm, and primary amputation often becomes the default solution for patients who cannot afford complex revascularization (Moxey et al., 2011).

The US Mixed Model

The United States operates a fragmented mosaic of all four models, and its amputation rate trajectory reflects a pattern of notable complexity rather than unidirectional failure. Longitudinal Medicare data document a meaningful period of progress: Goodney et al. (2013) demonstrated that major lower-extremity amputation rates declined substantially among Medicare beneficiaries from

the early 1990s through the early 2010s, concurrent with increased rates of both surgical bypass and endovascular revascularization—a finding that underscores the measurable impact of expanded vascular intervention on limb outcomes within the US system. However, this improvement was not sustained. Weaver et al. (2024) documented a subsequent reversal, with below-knee amputations (BKA) rising to approximately 13 per 100,000 and above-knee amputations (AKA) to approximately 8 per 100,000 by 2021—a combined rate of approximately 21 per 100,000, and substantially higher than peer nations such as the UK and Netherlands. The Commonwealth Fund's *Mirror, Mirror* 2024 report ranked the US last overall among 10 high-income countries on health outcomes, though it should be noted that some health policy researchers have argued that this ranking's equity-weighted methodology structurally disadvantages the US relative to its clinical performance in certain domains (Papanicolas et al., 2018); the pattern of elevated amputation rates, however, is independently corroborated across multiple data sources. The fee-for-service reimbursement environment, which structures payment around procedural volume rather than longitudinal outcomes, has been identified as a contributing factor to this reversal, prompting the CMS policy goal of transitioning all Medicare beneficiaries to Value-Based Care arrangements by 2030 (CMS, 2025; CMS Innovation Center, 2022).

Global Themes

A pervasive finding across recent literature is that, irrespective of a health system's financial resources, formal physician education in wound pathophysiology remains fundamentally deficient (Gould & Herman, 2025). Currently, wound management is rarely taught as a cohesive, standalone clinical discipline; rather, it is heavily

Table 2: Metabolic Burden, Systemic Buffering Capacity, and Amputation Outcomes by Health Model

Health System Model	Metabolic 'input' (Obesity & Diabetes Burden)	Systemic 'Buffer' (Preventive Infrastucture)	Amputation Rate (per 100,000)
Beveridge (UK, Spain, NZ)	Moderate - High sugar/fat intake; managed via state-led obesity task forces.	Strong - Universal primary care acts as gatekeeper to catch early PAD	**LOW** **2.9 - 8.3 per 100k** **✓ Controlled by standardization**
Bismarck (Germany, Japan, France)	Varied - Low in Japan; moderate in Germany; high smoking-related PAD	Maximal - World leading specialist density; rapid revascularization for elderly	**MODERATE** **4.3 - 8.6 per 100k** **✓ Stable despite aging population**
NHI (Canada, Taiwan, S. Korea)	High / Rising - Significant obesity (Canada); rapid urbanization (Taiwan)	Efficient - Single-payer data enables predictive models to target high risk feet	**STABLE** **5.0 - 7.0 per 100k** **✓ Balanced by cost-control pathways**
U.S. Mixed (Fragmented)	Critical - World-leading obesity & Type 2 Diabetes	Fragmented - High innovation, but 'amputation deserts' and fraud limit access	**HIGHEST** **12.0 - 40.0 per 100k** **× Driven by systemic misalignment**
Out-of-Pocket (Low-Income Nations)	Emerging - Double burden of malnutrition and rising urban obesity	Weak - Lack of infrastructure; PAD undiagnosed until limb necrotic	**SEVERE** **UP TO 24.4 ASYR** **× Highest disability burden**

Low amputation rate (well-buffered)
Stable amputation rate
High/Severe amputation rate
Strong systemic buffer
Weak/Fragmented buffer

fragmented across dermatology, surgical and primary care rotations (Reiter et al., 2025). Because traditional curricula often isolate the physical wound from the whole patient, emerging clinicians are systematically underprepared to manage the underlying metabolic and systemic drivers of non-healing wounds.

Integrated systems such as the Beveridge, Bismarck and National Health Insurance (NHI) models consistently maintain low to moderate amputation rates (ranging from 2.9 to 8.6 per 100,000) despite facing moderate, high, or rising metabolic burdens and aging populations. They achieve this stabilization through robust systemic buffers, including state-led preventive task forces, universal primary care gatekeeping, world-leading specialist density and predictive clinical pathways.

A fundamental determinant of a health-care system's efficacy is its underlying ontological approach to wound care. The paradigm through which a lower-extremity ulcer is perceived—either as a localized, topical lesion or as a manifestation of profound systemic pathology—constitutes a critical barrier to effective limb preservation. This ideological divide, long characterized by wound specialists as the "hole versus whole" perspective (Sussman & Bates-Jensen, 2012), underscores the dichotomy between procedurally driven sickness management and integrated, preventive health maintenance.

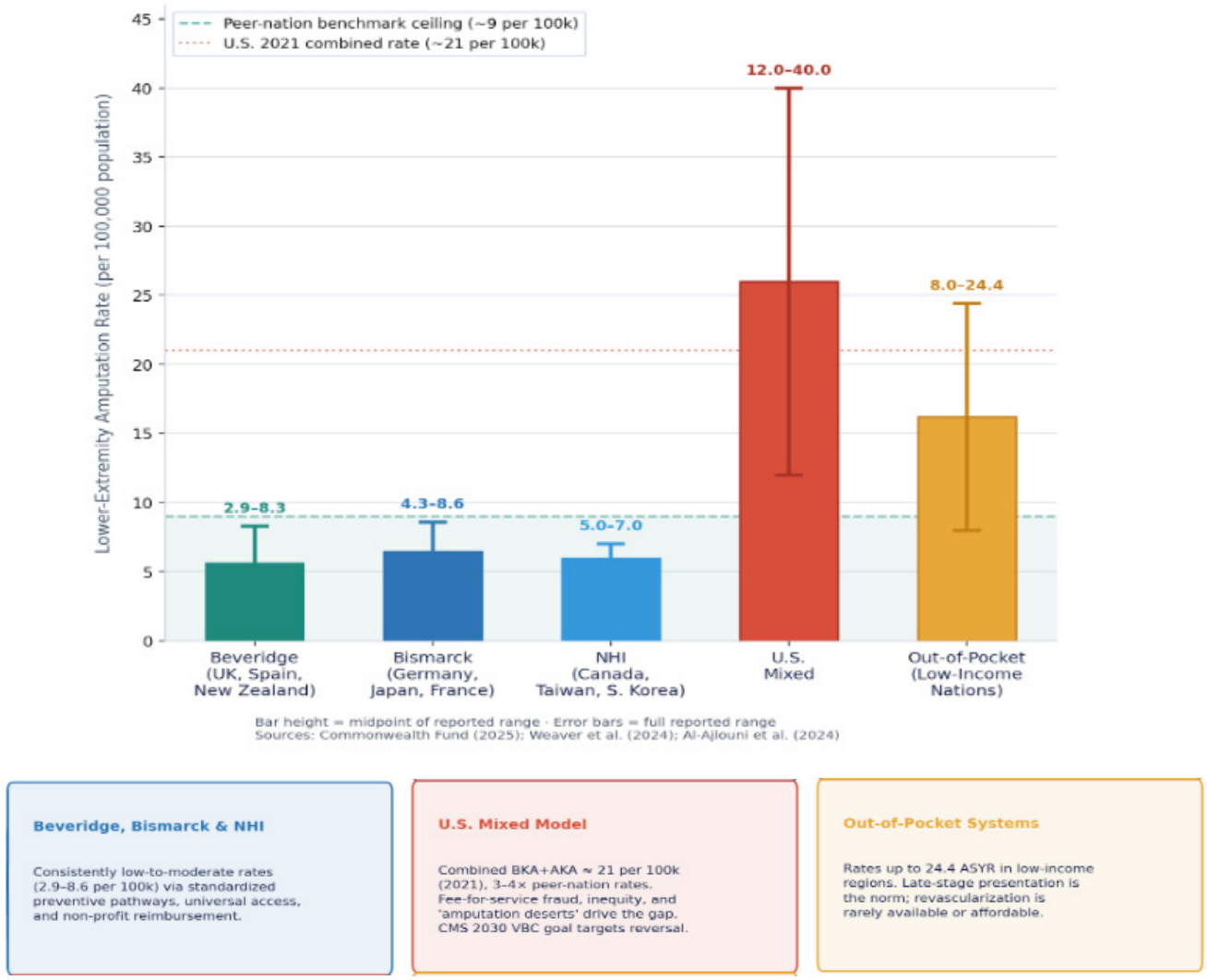
Regardless of the specific health-care delivery model, prevailing clinical and economic data consistently demonstrate that limb salvage represents a fundamentally superior long-term financial investment compared to amputation. Cost-effectiveness analyses of revascularization strategies for critical limb ischemia demonstrate that both endovascular and surgical approaches produce lower 10-year total costs than primary amputation while generating greater health benefits measured in years of ambulatory function and quality-adjusted life-years (Barshes et al., 2014). The NIH-funded Lower Extremity Assessment Project (LEAP)—the largest prospective multicentre study of limb-threatening injuries—projected lifetime health-care costs of $509,275 (all figures in USD) per amputee versus $163,282 for limb reconstruction, a difference exceeding three to one (MacKenzie et al., 2007). It should be noted that the LEAP cohort comprised primarily younger patients (mean age approximately 35 years) with traumatic lower-extremity injuries at Level I trauma centres; while derived from a trauma population rather than the older dysvascular or diabetic foot cohort that accounts for the majority of non-traumatic amputations. LEAP, nonetheless provides the most methodologically rigorous prospective lifetime cost estimate available in the peer-reviewed literature. Adjusted to current medical cost dollars using Bureau of Labor Statistics medical cost inflation (CPI for medical care services, 2007–2024; approximate multiplier 1.48), this per-patient lifetime burden well exceeds $700,000 (all figures in US) (MacKenzie et al., 2007). A national simulation model applied this per-patient estimate across the annual US lower-extremity amputation volume and estimated aggregate lifetime direct health-care costs at $46.7 billion, with a formal limb salvage program projected to reduce this burden by $15.2 to $38.5 billion depending on salvage rate assumptions (Tan et al., 2016; derived from a conference simulation model; peer-reviewed replication has not yet been published, and these projections should be interpreted accordingly).

A macro-level analysis of global amputation rates reveals a striking epidemiological paradox: both resource-constrained Out-of-Pocket systems and the exponentially high-expenditure United States Mixed model exhibit the highest global incidences of lower extremity limb loss, albeit driven by fundamentally divergent systemic mechanisms. The Beveridge, Bismarck and NHI Models demonstrate optimal preservation—maintaining major amputation rates of merely 5.6 to 6.5 per 100,000 population through standardized primary care gatekeeping, universal access to prophylactic podiatric screening and non-profit reimbursement structures. By contrast, US below-knee amputation (BKA) rates had risen to approximately 13 per 100,000 and above-knee amputation (AKA) rates to approximately 8 per 100,000 by 2021—a combined burden roughly three to four times greater than peer nations (Weaver et al., 2024). (See Tables 2 and 3.)

Table 3: Health System Expenditure, Chronic Disease Burden, and Amputation Outcomes

Health System Model	Health Spend (% of GDP)	Chronic Disease Burden	Amputation Rate (per 100,000)	Mirror, Mirror 2024 Rank
Beveridge (UK)	~10 - 12%	Moderate	**2.9 - 8.3**	**Top Tier (High Equity)**
Bismarck (Germany)	~11 - 13%	Moderate / High	**4.3 - 8.6**	**Top Tier (High Access)**
NHI (Canada)	~11 - 12%	High	**5.0 - 7.0**	**Mid Tier**
U.S. Mixed	17.3%	Critical	**12.0 - 40.0**	**Last (Worst Outcomes)**
Out-Of-Pocket	< 5%	Emerging	**Up to 24.4 (ASYR)**	**NA**

Graph 1: Lower-Extremity Amputation Rate by Global Health System Model



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Section III. The Middle East and North Africa (MENA) Region: A Landscape of Contrasts

No region in the world more starkly illustrates the relationship between political architecture, health system design and amputation outcomes than the Middle East and North Africa (MENA). Spanning 21 countries and over 600 million people, MENA is not a monolithic system but a deeply heterogeneous mosaic. Within its borders coexist petro-state tertiary care centres equipped with the latest endovascular technology, conflict zones where surgeons perform limb amputations without anesthesia and transitional hybrid systems navigating the tension between expanding coverage and entrenched structural fragmentation.

The metabolic burden confronting this region is arguably the highest on earth. According to the International Diabetes Federation, 73 million adults in the MENA region are currently living with diabetes (IDF Diabetes Atlas, 10th ed., 2021; updated to 85 million in IDF Diabetes Atlas, 11th ed., 2024)—a figure that represents the largest proportional share of any IDF region globally. More than one in five people in Africa and the Middle East combined are affected by diabetes, alongside foot ulcers or amputations—the highest burden of any world region (IDF Diabetes Atlas, 2021). The Global Burden of Disease dataset, analyzed across 21 MENA nations from 1990 to 2019, documents an overall annual increase of 1.39% in age-standardized LEA incidence rates (Al-Ajlouni et al., 2024).

The Gulf States: Advanced Capability, Structural Gaps

The high-income Gulf Cooperation Council (GCC) states—Saudi Arabia, the United Arab Emirates, Qatar, Kuwait, Bahrain and Oman—represent the most resource-advanced tier of MENA's health-care landscape. A 2025 Gulf Consensus document published by Wounds International formalized region-specific clinical guidelines advocating for annual diabetic foot screening, ankle-brachial pressure index (ABPI) assessment and standardized referral pathways for revascularization.

However, clinical sophistication at the tertiary level has not been matched by robust primary prevention infrastructure. A scoping review of diabetic foot disease management in GCC countries found that 72% of patients with diabetes in the UAE lack access to crucial foot care (Alessa et al., 2025). Furthermore, only Saudi Arabia among all 22 Arab nations has published national incidence studies on diabetic-related amputations; 17 countries report no prevalence data whatsoever. Without the data architecture to identify high-risk populations proactively, even well-resourced Gulf health systems default to treating late-stage disease rather than preventing it.

Conflict Zones: Traumatic Amputation As Health-care Systems Collapse

At the opposite pole of the MENA spectrum, conflict-affected nations present a profoundly different limb loss crisis—one driven primarily by traumatic injury and the wholesale destruction of health-care infrastructure. The GBD dataset documents that Syria, Yemen and Afghanistan registered the most dramatic increases in LEA rates across the entire MENA region between 1990

and 2019, with Syria recording a gross percentage increase of 330% in male LEA rates and 377.8% in female rates (Al-Ajlouni et al., 2024). In Yemen, 76% of all amputations over the 2016–2024 period were directly attributable to war-related injuries—predominantly affecting young male civilians with a mean age of 28 years (Hammad et al., 2025). By 2017, the Syrian Civil War had produced an estimated 86,000 amputations and 1.5 million permanent disabilities (WHO EMRO, 2025).

The ongoing conflict in Gaza has produced a particularly acute amputation crisis. Save the Children reported that more than 1,000 children underwent leg amputations in the first two months of conflict alone—a figure corroborated by field reports from UNICEF and the World Health Organization (Save the Children, 2024). Many of these procedures were performed without anesthesia due to critical supply shortages—representing the terminal endpoint of health-care system collapse.

Egypt: The Transitional Hybrid and Its Limb Preservation Paradox

Egypt occupies a unique and instructive position within MENA's health-care mosaic: it is a nation large enough—at over 100 million people—to constitute a health-care system unto itself, ambitious enough to have legislated universal coverage, and structurally complex enough that those ambitions remain partially unrealized. With a diabetes prevalence of 20.9% among adults, Egypt carries an enormous metabolic burden whose clinical consequences manifest disproportionately as diabetic foot disease, peripheral arterial disease (PAD) and ultimately lower-extremity amputation (IDF Diabetes Atlas, 2021).

A study from Alexandria University's Diabetic Foot Screening Clinic found that among 2,000 consecutive adult patients with diabetes, 4.4% had a documented history of non-traumatic amputation and 8.7% presented with active ulceration—reflecting a pattern of late-stage clinical presentation that is the hallmark of systems lacking effective primary prevention (El-Nahas et al., 2009); though derived from a single centre over a decade ago, this pattern is consistent with more recent observations of delayed presentation in Egyptian tertiary settings. Critically, one analysis found that treating a severe diabetic foot wound in Egypt may require up to 62.3 months of average salary—the highest financial burden of any country studied globally—rendering timely specialist care economically inaccessible for the majority of the population (Dhatariya & Abbas, 2025).

Egypt's Health-care System: Structure And The UHI Reform

For decades, Egypt's health-care system was characterized by four structural deficiencies: a fragmented regulatory and financing architecture, out-of-pocket expenditures comprising over 60% of current health expenditure, inadequate public funding at merely 1.5% of GDP, and a geographical imbalance in the distribution of skilled health-care workers. The Universal Health Insurance (UHI) Law of 2018 represents the most ambitious structural reform in the country's health-care history. The benefit package covers over 3,000 health services including surgical operations, prosthetic devices and complex diagnostic imaging (iPMI Global, 2024). Full national rollout is planned across six phases over 15 years, with completion anticipated by 2032–2033.

Early outcome data on the UHI are cautiously encouraging. A cross-sectional study conducted in 2021–2022 found that UHI beneficiaries reported an 80% greater likelihood of perceiving good overall accessibility. However, the same study found no statistically significant improvement in perceived quality of care between the two groups—a critical distinction. Expanded access to a fragmented, inadequately resourced system does not automatically translate into improved clinical outcomes (Hammad et al., 2025).

The Limb Preservation Gap: Late Presentation And The Default To Amputation

Despite the structural promise of the UHI reform, the clinical reality for Egypt's diabetic foot patients reflects entrenched systemic barriers that legislative change has not yet resolved.

The most consequential of these is the pattern of late-stage clinical presentation. By the time a patient with a diabetic foot ulcer presents to a university hospital, the wound has frequently progressed to deep tissue infection, osteomyelitis, or critical limb ischemia—stages at which revascularization is technically complex, outcomes are uncertain and major amputation often becomes the most expedient available intervention.

This dynamic is reinforced by the absence of standardized multidisciplinary limb salvage programs in Egyptian public hospitals. Referral pathways remain largely ad hoc, specialist density outside major academic centres is low, and outcome-based reimbursement mechanisms are absent from the current UHI framework. In this environment, major amputation functions as a rapid, definitive solution to a complex problem that the surrounding system is not yet structurally equipped to solve through limb preservation. It is, in the language of this analysis, an institutional default rather than a clinical last resort.

Emerging Pathways And The Road Forward

Despite these challenges, there are meaningful emerging signals of reform in both Egypt and the broader MENA region. Egypt's UHI system, when fully implemented, will represent the largest expansion of health-care access in the nation's modern history and will create the financing architecture necessary—if not yet sufficient—to support systematic limb salvage programs. The critical next step is embedding outcome-based reimbursement within the UHI framework: ensuring that providers are financially rewarded for healed wounds and preserved limbs rather than merely for surgical throughput.

Across the broader MENA region, growing recognition of unmet rehabilitation needs aligns with the WHO's Rehabilitation 2030 initiative, which has documented that in many low- and middle-income countries more than 50% of people do not receive the rehabilitation services they require (World Health Organization, 2017). The MENA region, taken as a whole, thus embodies the full spectrum of amputation causation: from the metabolic-preventable to the trauma-inevitable, from the resource-constrained to the capacity-constrained, from the legislatively ambitious to the structurally collapsed.

Section IV. The United States

Structural and Behavioural Drivers Of The US Amputation Crisis

Lower-extremity amputation trends in the United States reflect a trajectory of greater complexity than aggregate comparisons with peer nations suggest. Longitudinal Medicare data analyzed by Goodney et al. (2013) documented substantial declines in major amputation rates from the early 1990s through the early 2010s, concurrent with increasing rates of both surgical bypass and percutaneous endovascular interventions—evidence that the US health-care system demonstrated measurable capacity for improvement when revascularization access expanded. The subsequent reversal documented by Weaver et al. (2024), with combined below- and above-knee amputation rates reaching approximately 21 per 100,000 by 2021, therefore warrants analysis not as evidence of static failure but as a system that achieved gains and then lost them—raising the clinically and policy-relevant question of which structural conditions enabled the earlier decline and which changes since eroded it. At the clinical level, the primary physiological substrate for non-traumatic lower-extremity amputation is the convergence of diabetes mellitus and peripheral artery disease (PAD): with over 38 million Americans currently managing diabetes (CDC, 2023), the at-risk population is both large and growing, creating a metabolic burden that places particular demands on preventive and vascular care infrastructure.

Social Determinants of Health (SDOH) independently influence amputation risk in ways that clinical intervention alone cannot fully offset. County-level analyses demonstrate that a $10,000 decrease in median household income correlates with a 4.4% increase in major amputation rates, establishing a precise socioeconomic gradient that operates independently of baseline metabolic burden (Hicks et al., 2023). Emerging

pharmacological evidence also suggests differential protective effects by drug class: a large Danish target trial emulation found that SGLT-2 inhibitor users had a modestly lower 6-year risk of diabetic foot disease compared with GLP-1 receptor agonist users, driven primarily by reduced peripheral neuropathy (Kristensen et al., 2026), indicating that medication access inequities compound the SDOH-driven disparity in amputation risk. This socioeconomic gradient is further potentiated by the physiological mechanism of allostatic load—the cumulative biological cost of chronic psychosocial stress, which drives sustained elevation of cortisol and inflammatory markers, accelerating endothelial dysfunction and atherosclerotic progression in chronically resource-constrained populations (McEwen, 1998).

Fraud And Abuse: The Systemic Economic Misalignment

The fee-for-service (FFS) reimbursement architecture creates structural incentives that, in the wound care context, have been documented to reward procedural volume over clinical outcomes. Recent evaluations by the Department of Health and Human Services Office of Inspector General (HHS OIG) found that Medicare Part B spending on skin substitutes in non-institutional settings escalated by over 640% within a two-year period, surpassing $10 billion annually by the end of 2024—a pattern the OIG characterized as reflecting a combination of fraud, waste, abuse and misaligned pricing incentives warranting urgent policy reform (HHS OIG, 2025). The enforcement record illustrates the downstream consequences of these incentive structures: federal prosecution of one medical conglomerate identified a $1.2 billion scheme involving medically unnecessary amniotic allografts administered to elderly and hospice patients. The owners—sentenced on October 7 and October 10, 2025, to 15.5 and 14 years respectively—were ordered to pay criminal restitution exceeding $1.2 billion and approximately $410 million in forfeitures; on December 12, 2025, they additionally agreed to pay $309 million to resolve civil liability under the False Claims Act (DOJ, 2025). When reimbursement structures reward the repeated application of high-cost biological products rather than coordinated chronic disease management, the clinical environment shifts away from the multidisciplinary, systems-level approach that the evidence base consistently identifies as necessary to prevent amputation.

The 2030 Transition: Value-Based Care And Innovation

The CMS Value-Based Care (VBC) goal of transitioning all Medicare beneficiaries to accountable care arrangements by 2030—a policy target rather than a legislated mandate—represents a structural response to the documented misalignment between reimbursement incentives and clinical outcomes under fee-for-service payment (CMS, 2025; CMS Innovation Center, 2022). The core mechanism is a shift from payment for procedural volume toward payment contingent on long-term preventive outcomes, creating a financial architecture in which preventing amputation becomes economically rational for the accountable care organization (CMS, 2024). This structural realignment is being accompanied by an emerging layer of digital health and artificial intelligence tools that operationalize predictive risk stratification at the point of care. Evidence supporting remote patient monitoring applications in high-risk diabetic populations—including sensor-based plantar pressure and temperature monitoring systems—suggests potential for earlier detection of impending ulceration, though the evidence base for population-level amputation reduction remains an active area of investigation (Bus et al., 2020; Najafi et al., 2017).

The Structural Threat: Why Value-Based Care Alone Is Insufficient

The United States' transition to Value-Based Care confronts a foundational paradox: VBC rewards outcomes that its underlying workforce and information architecture are not yet consistently equipped to deliver. Chronic wound management

sits at the precise intersection of this gap. Despite costing Medicare an estimated $22.5 billion annually and affecting approximately 10.5 million Medicare beneficiaries, chronic wounds remain conspicuously absent from the CMS quality measure portfolio—none of the episode-based measures currently proposed under MACRA encompasses wound care (Nussbaum et al., 2018). When a payment system does not measure wound healing, it cannot reward it—and the fragmented specialist referral patterns, delayed advanced therapy adoption and inequitable geographic distribution of wound expertise remain structurally unchallenged.

The Educational And Credentialing Imperative

The clinical evidence establishing the superiority of integrated, team-based wound care is robust and consistent: multidisciplinary diabetic foot teams reduce major amputations by 48% to 70% in controlled settings (Santema et al., 2021). Yet the United States currently lacks a standardized, nationally required competency framework that ensures every clinician who encounters a chronic wound possesses a baseline of integrated wound assessment knowledge anchored in chronic disease context.

The solution therefore requires a parallel architecture alongside VBC: mandatory interprofessional wound care competency education embedded within existing health professional programs, site-of-care credentialing requirements for facilities managing wound-bearing populations under accountable care contracts, and evidence-based clinical pathways that are actively integrated into Electronic Medical Record (EMR) systems via clinical decision support tools. Machine learning models trained on wound characteristics and comorbidity profiles have demonstrated AUC values of 0.82–0.90 for predicting major amputation risk at the point of hospital admission (Oei et al., 2025)—precisely the inflection point at which early intervention remains mechanistically and economically viable.

The Wound As A Turning Point: A Call To Reframe

The United States is a nation of profound demographic and socioeconomic complexity. What these populations share, however, is not a common risk factor profile but a common system failure: the absence of an integrated approach that treats the chronic wound not as an isolated dermatological event to be dressed and rebilled, but as the visible signal of chronic disease that has not been adequately managed at every prior inflection point in the care cascade.

A healed wound is not merely a dermatological success. It represents demonstrated glycemic control, resolved vascular ischemia, managed infection, adequate nutrition, adherent offloading, and sustained patient engagement with a coordinated care team. If the wound is the endpoint of chronic disease management failure, then the healed wound and the amputation-free patient is the most concrete and measurable expression of chronic disease management success. The wound outcome is not merely a quality indicator for wound care; it is a quality indicator for the entire system that produced or prevented it (Nussbaum et al., 2018; Sen, 2025; Hicks et al., 2023).

The pathway forward is not VBC alone—nor education alone, nor AI alone—but their deliberate co-design. A VBC framework that includes wound-specific quality measures (healed wound rate, amputation-free days, time to advanced therapy) creates the financial architecture. Mandatory interprofessional wound care competency builds the human architecture. AI-enabled EMR decision support builds the informational architecture. And the unifying clinical principle—that the wound is part of the human, that the human lives within a chronic disease trajectory—provides the philosophical architecture that makes the others coherent.

Section V. Conclusion And Call To Action

Across the four global health system models examined in this analysis—Beveridge, Bismarck, National Health Insurance and Out-of-Pocket—and across the highly contrasting regional paradigms of MENA and the United States, one principle has emerged with unambiguous clarity: the amputation rate is not a random clinical outcome. It is a structural verdict. It reflects, with devastating precision, whether a health system has chosen to invest in prevention or wait for crisis, to coordinate care or fragment it, to reward healing or incentivize procedure.

The evidence reviewed in this analysis converges on several universal findings. First, metabolic burden alone does not determine amputation rates; the Beveridge and Bismarck models demonstrate that populations with moderate to high diabetes prevalence and aging demographics can maintain low LEA rates through standardized gatekeeping, universal access, and reimbursement structures that prioritize preventive outcomes. Second, systemic fragmentation is the most powerful predictor of elevated amputation incidence—whether that fragmentation manifests as the fee-for-service incentive misalignment of the United States, the referral pathway breakdown of Egypt's transitional system, or the infrastructure collapse of conflict-affected MENA nations. Third, the financial case for limb preservation is incontrovertible: the NIH-funded Lower Extremity Assessment Project established projected lifetime health-care costs of $509,275 per amputee versus $163,282 for reconstruction—a difference exceeding three to one (MacKenzie et al., 2007). This estimate derives from a trauma cohort of primarily younger patients (mean age approximately 35 years) at Level I trauma centres, rather than the older dysvascular or diabetic foot population that accounts for the majority of non-traumatic amputations; direct extrapolation to diabetic foot cohorts therefore requires interpretive caution. Nonetheless, adjusted to current medical cost dollars using Bureau of Labor Statistics CPI for medical care services (2007–2024; approximate multiplier 1.48), this per-patient lifetime burden well exceeds $700,000—making investment in early revascularization and multidisciplinary wound care not only clinically superior but economically rational by any defensible measure.

Crucially, the evidence confirms that wound-level intervention in the absence of systemic chronic disease management does not prevent amputation. A systematic review and meta-analysis of 57 studies found that structured multidisciplinary teams—integrating glycemic control, vascular assessment, infection management and wound care within a coordinated pathway—reduced major lower-extremity amputation risk by 48% relative to fragmented care (Santema et al., 2021; Musuuza et al., 2020). The organizational architecture of the health system, therefore, is not a background condition for wound outcomes—it is the primary determinant of them.

Looking forward, the global inflection points identified in this analysis offer genuine cause for cautious optimism. The US CMS goal of transitioning all Medicare beneficiaries to Value-Based Care arrangements by 2030 represents the most significant structural recalibration of the world's largest health-care economy toward prevention and healing outcomes. The core principle underlying this shift—that reimbursement structures should reward healed wounds and preserved limbs rather than procedural volume—has potential relevance beyond the US context. However, the structural, fiscal and institutional conditions that shape how outcome-based payment functions in a fragmented multi-payer environment differ substantially from those of Egypt's nascent universal insurance framework, the Gulf states' predominantly tax-financed tertiary systems, or the single-payer architectures of the Beveridge and NHI models. Transferability of specific VBC mechanisms therefore cannot be assumed; each system would require careful contextual evaluation to identify which elements are adaptable and which require fundamental redesign to fit local financing and governance realities. Egypt's Universal Health Insurance system, despite its implementation challenges, establishes the financing and institutional foundation upon which outcome-

oriented limb salvage pathways can eventually be built. Across the Gulf states, the formalization of regional diabetic foot guidelines signals a maturation from reactive tertiary care toward proactive population health management.

The call to action that emerges from this analysis is addressed to policymakers, clinicians, educators and health system architects worldwide. It demands, first, that physician education systems globally be reformed to treat chronic wound management, not as a peripheral clinical footnote, but as a core competency.

A note on comparability and generalizability:
The health systems examined in this analysis—spanning Beveridge, Bismarck, National Health Insurance and Out-of-Pocket financing models, and encompassing the highly divergent regional contexts of the United States and MENA—differ profoundly in their structural, fiscal, cultural and institutional foundations. Meaningful differences exist not only between national systems but frequently within them, across regions, payers and populations. As a result, direct, equitable comparison across these systems is inherently limited, and the generalizability of any single system's findings or interventions to another cannot be assumed. What this analysis does offer, however, is an identification of recurring themes—patterns that appear across multiple systems and contexts—that may represent causal drivers of amputation outcomes, meaningful correlates, or both. Whether causative or correlative, these shared patterns are noteworthy and merit rigorous scrutiny. Equally, each system examined demonstrates notable areas of measurable success in limb preservation that are themselves worthy of careful study, with the aim of identifying which elements may be adaptable and expandable within different systemic contexts. Most fundamentally, amputation is not a national or single-system problem. It is a global one. A cross-system, global-level analysis—however imperfect in its comparability—enables a breadth of policy discussion that no single-country examination can provide, and it is precisely this broader lens that creates space for more comprehensive, structurally informed advocacy for change.

It demands that health systems at every income level establish national diabetes registries and amputation surveillance databases, because what cannot be measured cannot be reduced. It demands that reimbursement architectures be restructured to reward healing velocity rather than procedural volume. And it demands that the amputation rate be formally adopted as a primary benchmark of health system performance. For those systems that have already achieved low amputation rates—the Beveridge, Bismarck, and NHI models examined here—the mandate extends further: to formalize outcome data sharing, publish transferable pathway models and engage in structured technical assistance with transitional and resource-constrained systems. High performance creates an obligation of knowledge export, not merely a benchmark for others to admire.

The legitimacy of amputation rate as a systems-level performance metric deserves direct defense. A parallel from within health care is instructive. Maternal mortality rate is accepted without controversy as one of the most powerful global benchmarks of health system performance—employed by the World Health Organization, the World Bank and every major global health institution as a sentinel indicator of whether upstream systems of access, prevention and coordinated care are functioning. No serious health policy scholar argues that maternal mortality rate is an invalid metric because most pregnancies do not end in maternal death, or because the structural differences between health systems make cross-national comparison imperfect. The metric is accepted precisely because it is rare, irreversible, and preventable—and because its rate, and the variation of that rate across systems and populations, reveals the cumulative performance of everything upstream: prenatal care access, skilled birth attendance, post-partum monitoring and the equity with which those resources are distributed. Amputation rate occupies an identical epistemological position. It is rare. It is irreversible. It is, in the overwhelming majority of cases, preventable. And its rate—and the profound variation of that rate across health systems,

income strata, and racial and geographic subpopulations—reflects with equal precision the cumulative performance of upstream systems: glycemic control access, primary care gatekeeping, vascular referral pathways, multidisciplinary wound care infrastructure and the equity with which each of those is distributed. To accept maternal mortality as a valid systems benchmark while declining to extend the same standing to amputation rate is not a methodological position—it is an oversight, and one this field can no longer afford.

Limb preservation is, at its core, a statement of values. It declares that a patient's mobility, independence and dignity are worth the sustained institutional investment required to protect them. Every health system that reduces its amputation rate has chosen, implicitly or explicitly, to prioritize human wholeness over procedural convenience. The aspiration of this analysis is that its findings contribute meaningfully to a world in which that choice becomes universal—and in which the loss of a limb to a preventable cause becomes, truly, the rare exception rather than the default.

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Examining A Persuasive Health Technology Intervention For Enhancing Foot And Leg Self-care In Patients With Peripheral Vascular Disease: A Single-group Pilot Study

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Abstract: The aim of this study was to: 1) examine participant perceptions of an email-based intervention to support foot health amongst persons with peripheral vascular disease (PVD) and 2) explore preliminary evidence of its usefulness in increasing frequency of foot and leg inspection. The intervention for this single-group pilot study consisted of a series of educational, supportive and reminder email messages delivered once per day for 60 days. Among the encouraged self-care behaviours, a simple daily inspection of the lower limbs and feet was emphasized. Participant perceptions were measured with items adapted from the Mobile Application Rating Scale at study end. Preliminary usefulness was measured with a single item concerning frequency of foot and leg inspection at baseline and study end. Sixty-five individuals participated and 20 withdrew. Participants who completed the user perceptions questionnaire generally viewed the intervention as helpful and persuasive, with at least 35/41 (85%) agreeing with items concerning use of it increasing awareness, intentions and care behaviour. Preliminary results concerning frequency of foot and leg inspection showed some improvements from baseline to study end. The study findings, while promising, point to the need for further evidence concerning the acceptability and effectiveness of email or text messages with randomized controlled trials.

Key words: *electronic mail, lower extremity, persuasive health technology, peripheral vascular disease, self-care, peripheral vascular disease*

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Peripheral vascular disease (PVD) is a serious chronic health problem involving compromised circulation outside the heart and brain.[1] The long-term sequelae include a greater susceptibility to lower-limb and foot wounds, which can lead to ulceration, infection, gangrene and, ultimately, surgical amputation.[2] As with persons with other chronic diseases, most individuals living with PVD will necessarily bear responsibility for managing most of their own day-to-day health and care,[3] supported intermittently by the health-care system.

According to Riegel et al.,[4] self-care refers to the process of maintaining health through health-promoting practices and managing illness. Self-care includes: a) self-care maintenance: behaviours performed to improve well-being, preserve health or to maintain physical or emotional stability; b) self-care monitoring: the process of regular, diligent body monitoring or surveillance, or 'body listening' in order to recognize that a change has occurred; and c) self-care management, i.e., evaluating the changes in physical or emotional signs and

symptoms to determine if further action is needed. Finding the best ways to support individual patients in their self-care activities is an ongoing challenge.

Persuasive health technology represents an extension of persuasive technology[5] and refers to "any technology purposely designed to influence, reinforce, change or shape health-related attitudes or behaviors".[6] These technologies typically draw upon theories of motivation, persuasion, and behaviour change.[7] There is a large range of technologies here, including many that could be accessed through a mobile phone.

It has been recommended that behavioural interventions should be feasible, uncomplicated, as convenient as possible and not unnecessarily time-consuming.[8-9] Four categories of persuasion principles were identified in the Persuasive System Design (PSD) model developed by Oinas-Kukkonen and Harjumaa: primary task support, dialogue support, credibility support and social support.[9] A recent systematic review by Almutairi et al. identified 11 PSD features that can increase patient engagement through using mobile device health, or mHealth, applications (apps), including: tailoring, personalization, self-monitoring, praise, reminders, suggestions, social role, trustworthiness, social learning and normative influence.[10] Nonetheless, the particular functionalities that are chosen for a persuasive health technology may best be determined considering the context, goals/objectives and real-world constraints.[6]

Recent research is ambivalent regarding the use of persuasive health technologies for foot health. Dincer and Bahcecik found significantly better knowledge, self-efficacy and foot care behaviour amongst those randomly assigned to use an animation-supported foot care app for persons with diabetes versus those who received standard in-clinic education.[11] Although Kilic and Karadag found significant improvements in knowledge, behaviour and self-efficacy in participants using their foot care app, the control group showed similar improvements in behaviour and self-efficacy.[12] Similarly, Marques et al. found no significant differences between intervention and control groups in their study of a mobile foot-care education app intervention.[13] However, the intragroup analyses revealed that the intervention group demonstrated increased frequency of foot self-assessments and adherence to foot self-care. Ogrin et al. used participant co-design for a foot-health app for people with diabetes.[14] The app was perceived positively, particularly for those newly diagnosed. However, uptake was low, with only 18/40 participants using it. Ploderer et al. identified three engagement patterns in their study of a foot care app: continuous, temporary and failed engagement.[15]

Messaging, whether through text (SMS/MMS) or email, has the potential to reach large audiences and possibly serve as an inexpensive intervention modality.[16-18] Few studies have examined messaging interventions for foot health. Hassan reported that, while 76% of participants with diabetes and no history of foot ulcers reported poor foot self-care initially, less than 1% reported poor foot self-care after receiving an in-clinic education session and two-three reinforcement text messages per week over the subsequent 12 weeks.[19]

Given the relative lack of research concerning persuasive health technology interventions in the PVD population, the aims of this study were twofold: to examine participant perceptions of an email-based intervention to support foot and leg health amongst persons with PVD, and second, to explore preliminary evidence of its usefulness in increasing frequency of foot and leg inspection.

Methods

Recruitment: Adults with PVD were recruited from an amputation clinic that provides ambulatory rehabilitation care and a peripheral vascular clinic in a city in Western Canada. To be eligible, participants required regular access to a smartphone or computer, at least one existing lower limb (below knee), functional English communication skills and sufficient cognitive ability to participate in the intervention. Clinic staff informed potentially eligible persons during clinic visits. If they expressed interest in learning more about the study, they met with

the study coordinator, an experienced nurse, who assessed eligibility. During recruitment, the study coordinator gave a verbal overview of the study and provided each interested person a study information letter. The coordinator answered any questions from prospective participants or reviewed the information letter with them, when requested. Participants were informed that the completion and return of each survey questionnaire would constitute consent to participate and permission for the researchers to use the data collected in the manner described in the information letter. Both the study information letter and the coordinator emphasized that participation was entirely voluntary, and that a participant's decision to participate or not would not affect the care they receive, and that they could withdraw from the study at any time. Participants were eligible to enter a draw for one of ten $20 gift cards. This study was approved on ethical grounds by the University of Saskatchewan Behavioural Research Ethics Board (BEH1732).

Intervention: The behavioural intervention focused on improving participants' knowledge, skills, and confidence. It was guided by the Persuasive Systems Design model,[9] incorporating principles under primary task support, computer-human dialogue support, system credibility support and social support. The intervention consisted of a series of educational, supportive and reminder email messages. Messages included simple text, copyright-free images and links to videos regarding recommended self-care behaviours. Some messages included more interactive elements, including asking if the participant had been carrying out the recommended behaviour and praising or encouraging, depending upon their response. To make the messages more attractive, images of [the province of] Saskatchewan, Canada and coloured backgrounds were also used.

Among the encouraged self-care behaviours, a simple daily inspection of the lower limbs and feet was emphasized. A daily inspection is recommended for at-risk individuals living with PVD.[2, 20, 21] The intervention included information to facilitate early identification of changes in the lower limb and foot that may indicate the early development of wounds and encourage prompt care-seeking and treatment when changes were noticed.

Message delivery was fully automated, and messages were sent to participants' email addresses via the REDCap system hosted at the University of Saskatchewan.[22-23] Participants received semi-randomly scheduled messages once per day over 60 days, from day six of study participation to day 65. There were 36 messages, so some were delivered repeatedly. Examples of messages are included in Figure 2.

Measures: Participants were asked to complete questionnaires at multiple time points, using REDCap electronic data capture tools. Demographics and baseline health information were measured at study start. User perceptions were measured after participants completed the study with items adapted from the Mobile App Rating Scale (MARS).[24] The MARS has been shown to have acceptable validity and reliability.[25]

Foot and leg inspection was measured with a single item at baseline, and then three, six and nine weeks later. At baseline, the item read: "How often do you (or the person you ask to help you) closely inspect your legs and feet, looking for changes from what they usually look, feel, or smell like?" The response options were: *every day, most days each week (4-6 days), some days each week (1-3 days), a few times a month, less than a few times a month*, or *I only inspect my legs or feet if I think there is a problem*. A version of this item was also asked during and after the intervention; however, on those days it asked participants to think back over the past two weeks. Results from participants who responded at baseline and study end are included here. Data collection occurred between February 2021 and January 2022.

Statistical Analysis: Descriptive analyses for this pilot study were performed using IBM SPSS Statistics (version 28). The McNemar test was used to examine changes in reported behaviour.

Table 1: Demographic information.

		Total sample (n=45) n (%)
Age		
	40-49y	4 (9%)
	50-59y	14 (31%)
	60-69y	20 (44%)
	70-79y	3 (7%)
	Over 79y	4 (9%)
Marital Status		
	Married or common-law	28 (62%)
	Divorced, widowed, or separated	9 (20%)
	Single, never married	7 (16%)
	Missing	1 (2%)
Education		
	Less than high school	1 (2%)
	High school diploma	9 (20%)
	College, trade, or other non-university certificate or diploma	20 (44%)
	University certificate, diploma, or degree	15 (33%)
Current Employment Status		
	Employed (full or part-time)	14 (31%)
	Retired	22 (49%)
	On leave or unable to work	6 (13%)
	Other	3 (7%)
Household Income		
	$10-40K	7 (16%)
	$40-70K	14 (31%)
	$70-100K	6 (13%)
	Over $100K	10 (22%)
Residence		
	Large city	25 (56%)
	Other city	10 (22%)
	Farm or acreage	7 (16%)
	Other	3 (7%)
Internet Use		
	Daily	37 (82%)
	A few times a week	8 (18%)

Results

Sixty-five persons with PVD participated and ten formally withdrew. In addition, five participants appeared not to have opened any emails and another five seemed to have ceased opening emails during the study, leaving 45 participants (17 females, 28 males). Median age band was 60-69y. Additional demographics are presented in Table 1. Baseline health measures are presented in Table 2 and user perceptions are presented in Table 3.

Table 2: Baseline health information.

		Total sample (n=45) n (%)
Self-rated Physical Health		
	Excellent	0
	Very good	4 (9%)
	Good	21 (47%)
	Fair	14 (31%)
	Poor	5 (11%)
	Missing	1 (2%)
Self-rated Mental Health		
	Excellent	5 (11%)
	Very good	11 (24%)
	Good	20 (44%)
	Fair	9 (20%)
Has a Health-care Provider told you that you have diabetes? (yes)		30 (67%)
Have you had a lower-limb amputation? (yes)		16 (36%)
Have you had a wound on your toes, feet or lower legs that healed slowly, poorly, or not at all? (yes)		28 (62%)
Medication to lower BP? (yes)		35 (78%)
Medication to thin blood? (yes)		22 (49%)
Medication to lower cholesterol? (yes)		27 (60%)
Currently smoke tobacco?		
	Daily	6 (13%)
	Less than daily	0
	Not at all	39 (87%)

Table 3: User perceptions results (n=41).

	Strongly disagree n (%)	Disagree n (%)	Neutral n (%)	Agree n (%)	Strongly agree n (%)	No opinion n (%)
This app is likely to increase people's awareness about the importance of caring for their legs and feet daily.	0	0	4 (10%)	25 (61%)	12 (29%)	
This app is likely to increase a person's knowledge/ understanding of why it is important to care for their legs and feet daily.	0	0	3 (7%)	26 (63%)	12 (29%)	
This app is likely to change people's attitudes about caring for their legs and feet daily.	0	0	4 (10%)	26 (63%)	10 (24%)	1 (2%)
This app is likely to increase people's intentions/ motivation to care for their legs and feet daily.	0	0	6 (15%)	30 (73%)	5 (12%)	
Use of this app is likely to encourage people to seek out additional help if they need support when caring for their legs and feet daily.	0	0	5 (12%)	27 (66%)	9wvw (22%)	
People using this app are likely to increase the number of days each week they care for their legs and feet.	0	0	6 (15%)	25 (63%)	9 (22%)	1 (missing)

		n (%)
Would you recommend this app to people who might benefit from using it?		
	Not at all. I would not recommend this app to anyone.	0
	There are very few people I would recommend this app to.	3 (7%)
	Maybe. There are several people whom I would recommend it to.	10 (24%)
	There are many people who I would recommend this app to.	4 (10%)
	Definitely. I would recommend this app to everyone who might benefit.	22 (54%)
	No opinion	2 (5%)
Did the app improve your knowledge about caring for your legs and feet?		
	Not really	1 (2%)
	A little bit, but mostly just reminded me of things I already knew.	8 (20%)
	Somewhat more.	16 (39%)
	Yes, I learned a great deal.	14 (34%)
	No opinion	2 (5%)
Did the app offer you useful skills and tips that help when caring for your legs and feet?		
	Not really	2 (5%)
	Maybe a little	8 (20%)
	Yes definitely	29 (71%)
	No opinion	2 (5%)
Do you think your experience with the app helped boost your confidence, when caring for your legs and feet?		
	Not really	3 (7%)
	Maybe a little	12 (29%)
	Yes definitely	24 (59%)
	No opinion	2 (5%)
Do you think a daily reminder (to inspect and wash the legs and feet), sent to peoples' smartphones from this app would be helpful?		
	Yes	7 (17%)
	Yes – if people had the option to turn the reminder on/off and set the time of day to receive the message.	19 (46%)
	No	3 (7%)
	Unsure	9 (22%)
	No opinion	3 (7%)

Self-care behaviour results are displayed in Figure 1. Thirty-nine completed the foot and leg inspection item at baseline and study end (16 females, 23 males). Four more participants reported daily inspections at study end (15/39, 38%) versus baseline (11/39, 28%; P=.39). There was a non-significant increase in those reporting inspections on at least, "most days each week (4-6 days)" from baseline (20/39, 51%) to study end (28/39, 72%; P=.06). Eleven increased their frequency to meet this threshold and three decreased their frequency below the threshold. However, looking at those reporting inspections at least "some days each week (1-3 days)", 24/39 (62%) reported this at baseline and 36/39 (92%) reported this at study end (P<.001). Twelve increased their frequency to meet this threshold and none decreased below the threshold.

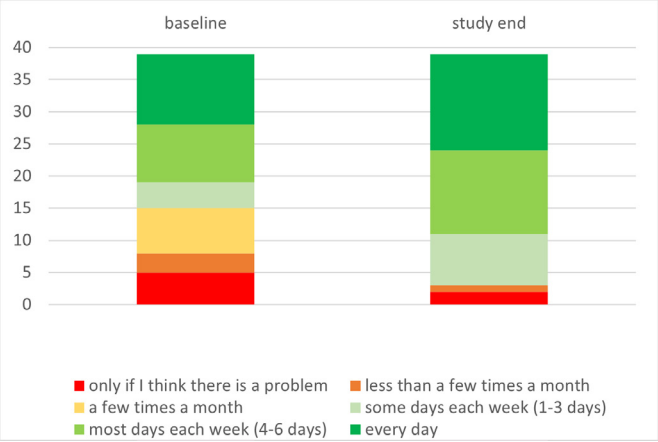

Figure 1: Frequency of leg/foot inspection (n=39).

Discussion

Participants who remained in the study generally viewed the intervention as helpful and persuasive. There was a small increase in the number of participants reporting inspections on at least four days each week and a large increase in those reporting inspections on at least one day each week. Global health-care systems are increasingly struggling to meet the acute and chronic needs of patients in the face of limited resources. As a solution, individuals are turning to self-management strategies to monitor and treat their personal health-care needs.[26] This is an interesting adaptive phenomenon reminiscent of pre-socialized medicine, whereby a nascent health-care system with limited resources often required individuals, their families and allied professionals to intervene with creative personalized solutions. At the same time, the use of persuasive technology, through advances in communication technology, is growing in health care.[6] Such technologies offer a promising approach to providing solutions to current system challenges by influencing patients to be more involved in their own health surveillance by changing behaviour in real time.

The findings reported here support and reinforce this trend in medical care. Previous research has found similar acceptability and utility results when studying foot health apps in people with diabetes. Ogrin et al. used participant co-design and their app was perceived positively; however uptake was low, with only 18/40 participants using it.[14] Hassan reported that, while 76% of participants with diabetes and no history of foot ulcers reported poor foot self-care initially, less than 1% reported poor foot self-care after receiving an in-clinic education session and two-three reinforcement text messages per week over the subsequent 12 weeks.[19]

Our intervention consisted of daily educational, supportive and reminder email messages concerning foot and leg health for persons with PVD. Participants did not unanimously endorse the helpfulness of the information included in the messages. Several reported that they already knew the information. It is also plausible that many of those who elected not to continue or to not fill out the user perceptions questionnaire did not find the information helpful. Many different kinds and intensities of interventions may be necessary, so that individuals can access those that they find acceptable and helpful.

Despite reported complications, there was a desire to engage in preventative strategies that would promote their perceived wellbeing. Complications such as general malaise, pain and loss of independence can present as a significant barrier to self-management.[27] It is apparent that persuasive technology was valued and embraced by the remaining participants who viewed it as a means

to improve their health outcomes even in the face of significant complications related to peripheral vascular disease.

Figure 2

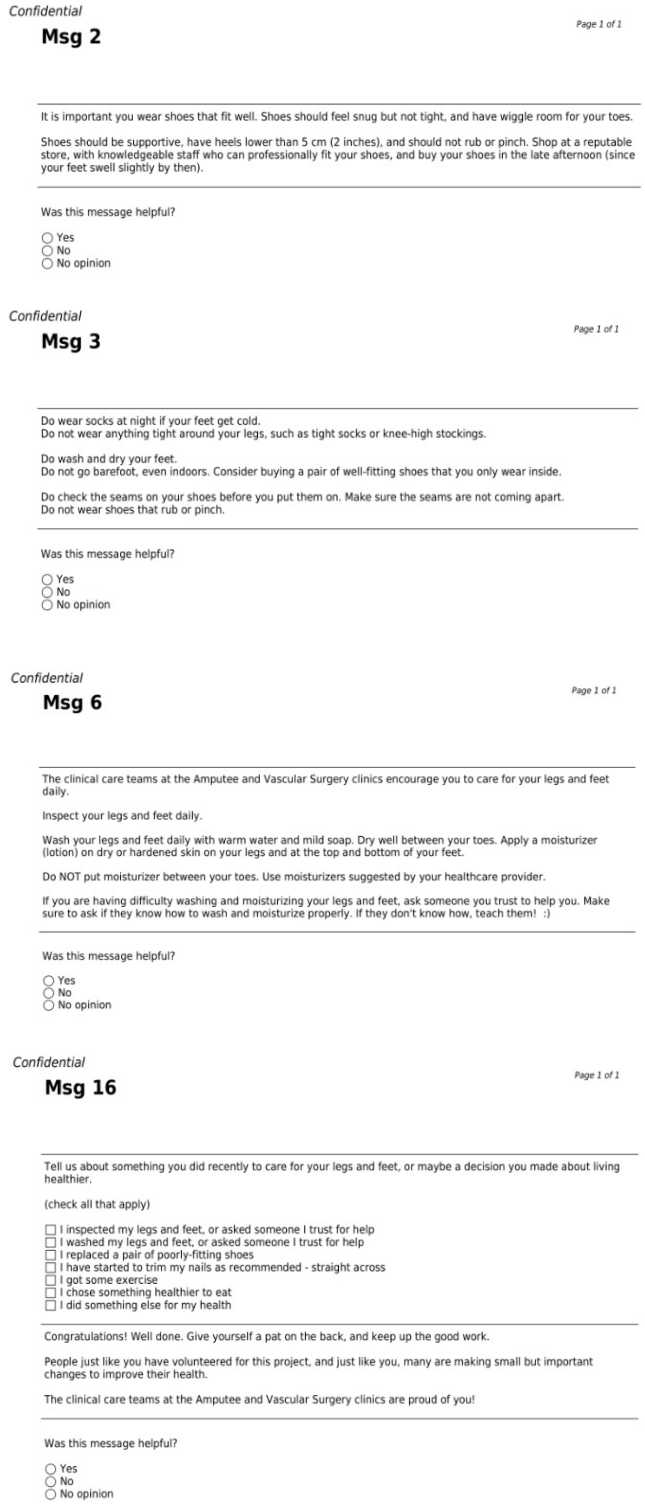

Figure 2 contains a sample of messages sent to participants. These interventions were developed using principles from the Persuasive Systems Design model.[9] Primary Task Support underscores the value of reducing complex behaviours into simple tasks to manage peripheral vascular disease. Behaviours such as regular inspection were encouraged in messages. Computer-human Dialogue Support is integral to ongoing engagement in persuasive health technology. Embedded in some of the messages were congratulations for task achievement followed by celebratory animation. Other messages reminded participants to inspect their feet by also rewarding them with congratulatory animation if they answered "yes". System Credibility Support was achieved by incorporating expert advice to persuade. In this case, referencing the need to care for their lower extremity as advocated by the teams in amputee and vascular clinics was embedded into messages.

A key component of persuasive technology is employing motivation techniques in a non-threatening manner to achieve positive outcomes.[9] Progressive monitoring, reminders or alert messages may contribute to encouraging and reinforcing behaviours. In this study, 63% (26/41) of the participants reported a desire to receive daily reminders to inspect and wash their lower extremity, underscoring the value of this technology in fostering self-care and engagement in real time. Also, nearly half (49%, 20/41) reported that it would be helpful for clinic staff to be able to see patient responses in order to reinforce and acknowledge their achievements and identify individuals who are struggling.

The Persuasive Systems Design (PSD) model describes principles that include social support mechanisms. Cooperation and competition were explored as motivating factors amongst participants in this study. Although comparison between participants can promote positive outcomes, participants were divided on this approach, with 49% (20/41) anticipating increased motivation to adopt healthier habits if the program anonymously compared their performance with others

performing the same self-care activity, while 20% (8/41) rejected the approach and 24% (10/41) were unsure. Respondents reported slightly more interest in cooperating or communicating with like individuals through support or online chat groups. Interestingly, when asked if they would support frank competition by awarding points for higher completion rates (resulting in small rewards), the majority (71%, 29/41) either responded negatively or weren't sure about this approach.

Limitations: Although results supported the intervention's potential acceptability and utility, this study had several limitations, which should be acknowledged. Firstly, generalizability may be a concern. The initial study sample was relatively small (N=65) and 15% (n=10) formally withdrew, along with another ten (15%) discontinuing. This is unfortunate; however, the authors agree with Jacobs,[28] that persuasive technology must always support the autonomy of persons, and that consent must be ongoing and explicit. Furthermore, data for these analyses were only available for approximately 87-91% of the remaining sample. Participants may have been better educated and of higher socioeconomic status than many with PVD. Finally, the study design precludes inferences concerning the effectiveness of the intervention. A properly powered randomized-controlled trial, which includes possible moderators (e.g., pain) is needed.

Conclusions

Our intervention, which consisted of daily emails concerning foot and leg health for those with PVD, was viewed positively by a majority of those who completed the end-of-study survey. Preliminary results concerning foot and leg inspection showed some improvements from baseline to study end. Participants reported increased frequency of foot and leg inspections at study end. Nonetheless, the generalizability of these results may be limited. Further evidence concerning the acceptability and effectiveness of email or text messages in this population should be sought using randomized controlled trials.

Ethics statement

This study was approved on ethical grounds by the University of Saskatchewan Behavioural Research Ethics Board (BEH1732).

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Conflict of interest/Funding

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Author contribution

DN analysed data and drafted and edited the manuscript. GL and DG oversaw project design and data collection and drafted and edited the manuscript. NO oversaw project design and data collection and edited the manuscript.

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Charcot Neuroarthropathy: Salvage Or Amputation? Tools For Decision Making

Michael B Strauss MD, **Karim A Manji** DPM, **Keith Penera** DPM and **Stuart S Miller** MD

Abstract: Charcot neuroarthropathy (CN) can be a challenging management problem. When advanced, it requires making decisions regarding complex salvage surgeries with extended convalescence versus leg amputations. It is essential to make informed decisions to attempt limb salvage versus proceeding to early-on amputation of a limb for patients with CN. This article presents three scoring tools to facilitate making salvage versus leg amputation decisions for CN using objective criteria.

Key words: *Charcot neuroarthropathy, limb salvage, amputation, decision making tools, foot and ankle*

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Charcot neuroarthropathy (CN) can be a challenging management problem. When advanced, it requires making decisions regarding complex salvage surgeries with extended convalescence versus leg amputations. Its most common presentations are on the foot and ankle. Presentations are consistently associated with neuropathy; with diabetes mellitus being the most common cause of the neuropathy.

The etiology of CN remains perplexing. Proposed causes of CN appear to be a combination of events including trauma, occult or overt; infection; inflammation and/or hyperemia secondary to loss of sympathetic vasomotor control. The consequences are resorption and eventual collapse of the bones of the foot and/or ankle.[1,2] This leads to deformities, wounds and inability of the foot and ankle to serve as stabilizing platforms for standing and walking. Complications from CN are potentially limb-threatening. Appropriate initial management includes stopping progression with rest and offloading, maintaining foot-leg alignment with a plantigrade foot and selecting appropriate protective footwear. When wounds and deformities become serious enough to consider amputations, surgeons' roles are to eliminate wounds and infections, correct deformities and realign the foot and ankle.

Limb preservation is the goal in most situations. Lower limb amputations may be appropriate when infection and/or pain is uncontrolled, compliance issues make it unlikely the patient will adhere to the six to nine-months of convalescence required, foot salvage will not improve the patient's mobility due to concurrent comorbidities, perfusion is inadequate for healing or combinations of these.[3]

It is essential to make informed decisions to attempt limb salvage versus proceeding to early-on amputation of a limb for patients with CN. Consideration also needs to be given to both cost-benefit/effectiveness and quality of life. In a subset of patients, primary amputation is the treatment of choice, due to the severity of the CN problem and consideration of the patients' overall health status and goals. To help us with this challenge, we utilize three user-friendly, objective 0-10 score evaluation tools. These are the *Wound, Wellness* and *Goal Scores*.[4-7] These three scoring tools facilitate making salvage versus leg amputation decisions for CN using objective criteria.

Objectifying Evaluation

Scoring systems have been formulated to stage and evaluate CN deformities, but little attention has been given to determining the severity of the deformity or wound. The Wagner diabetic foot wound classification and management system is not applicable for CN problems. All decisions in the Wagner system regarding salvage versus amputation are based on ankle-brachial indices and deformity is only mentioned in his Grade-0 (no wound with underlying bone deformity). In our experiences, perfusion is not the problem with CN. This is consistent with the pathophysiology previously described. We are unaware of any scoring systems used in the evaluation and management of CN that help with decision making for limb-salvage versus amputation.

Surgery needs to be considered for patients with Charcot if there is a deformity not manageable with customized protective foot wear and/or bracing, deeply infected wound, limb threatening foot ischemia, rapidly progressive deformity or combinations of these. The goal of reconstruction is a stable, plantigrade foot aligned with the leg and amenable to ambulation with protective footwear. The challenge is how to add objectivity to decision making for limb salvage versus amputation in the patient with the outlined problems. The three scoring tools meet this requirement. The scores use objective criteria for each grade, can be rapidly ascertained and interpretations become intuitively obvious. These tools were adapted from the lead author's Long Beach Strauss Wound Score and his work on limb preservation, along with the co-authors' career experiences. Our algorithm provides a guide for evaluation and management of the CN spectrum (See Figure 1).

Long Beach Strauss Wound Score

This score quantifies the seriousness of a wound. It is derived by summing five assessments. These include: 1) Appearance of the wound, 2) Size, 3) Depth, 4) Infection and 5) Perfusion (See Table 1).

Table 1:

Long Beach Strauss Wound Score

Assessment/ Grade points	2	1.5	1	0.5	0
Appearance Base/skin margins	◯ Healthy	◯ Maceration	◯ Yellow/White	◯ Exudate	◯ Black/Necrotic
Size Include recesses	◯ < Thumb Print	◯ In-between	◯ TP-to-fist	◯ In between	◯ > Fist
Depth Include tract depth	◯ Skin	◯ Subcutaneous	◯ Muscle/Tendon	◯ Bursa/Cicatrix	◯ Bone/Joint
Sepsis	◯ Skin Flora	◯ Contamination	◯ Localized Abscess Osteo Cellulitus Indur	◯ Left shift	◯ Systemic Fever/Chills Dysgly/B-remia
Perfusion Colour, Temperature, Capillary refill	◯ Palpable Pulses Pink Warm<2 sec	◯ Mixed findings	◯ Doppler Pale Cool 2-5 sec	◯ In between	◯ Imperceptible Cold > 5 sec Black-White

LBSWS_____Pts **Wound Type:** ☐ **Healthy** 7½ to 10-Pts ☐ **Problem** 3½ to 7-Pts ☐ **End-stage** 0 to 3-Pts

Legend: B-remia = Bacteremia, **Dysgl** = Dysglyemia, **Osteo** = Osteomyelitis, **Pts** = Points, **TP** = Thumb print

This score integrates the main criteria used by four of the most commonly used diabetic foot wound scoring systems; namely perfusion (Wagner which uses the ankle-brachial index),[8,9] infection (Infectious Disease Society of America Diabetic Foot Infection guidelines),[10] depth (National Pressure Injury Advisory Panel grades)[11] and infection + ischemia + depth (San Antonio Texas/Lavery classification).[12] The Long Beach Strauss Wound Score (LBSWS) provides objective (i.e., quantifiable) criteria for amputation, i.e., LBSWS ≤3-points that are not amenable to revascularization or, if done, are not beneficial versus justification for salvage (LBSWS ≥3,5 Points). However, patients with an LBSWS in a 'Transition Zone' (2.5 to 4-points) who are motivated to avoid an amputation require additional information before making the salvage/amputation decision. This is provided by using objective-derived information from our Wellness (WS) and Goal (GS) Scores.[13-16]

Wellness Score

This score provides information that is obtainable from the initial evaluation of the patient with a wound or deformity (See Table 2). While scores such as the SF-MPQ-2, the FRAIL index and the Charlson Score provide systems to evaluate health status, they use differing assessments, without the scores being intuitive to interpret. The Wellness Score (WS), like the LBSWS, is a 0 to 10-point scoring system that uses five assessments with each graded on 2 (best) to 0-point (worse) objective criteria. It also becomes intuitively obvious, like the LBSWS, that high scores on the 10-point scale are desirable and low scores reflect worrisome health and function concerns. The WS summarizes the assessments of: 1) Ability to do activities of daily living, 2) Ambulation, 3) Co-morbidities (excluding the separate assessment of neurological status), 4) Inhibitors (e.g., smoking, steroids, and/or antimetabolites) and 5) Neurological impairment (See Table 2).

The WS offers guidance for deciding when collaboration with specialists is indicated. This is almost always necessary when making salvage versus amputation decisions in the impaired or decompensated host. Thus, information helps in patients whose comorbidities are so severe that limb salvage will not improve their mobility or quality of life. Wellness Scores in the 0 to 3-point range are associated with the decompensated patient who is bedridden, minimally to non-responsive and has serious wounds, with or without joint contractures. The Wellness Score provides objective information for what management decisions, i.e., foot salvage, leg amputation, minimal infection source-control surgeries or comfort care measures should be done.

Wellness Score

Differentiating Biological from Chronological Ages

Assessment/ Grade	2-Points	1-Point	0-Points
	Use half points if grades are mixed or intermediate between 2-points		
ADLs Activities of daily living	○ Full	○ Some	○ None
Ambulation Minus 1/2 point if aids required	○ Community	○ Household Minus ½ point if aids required	○ None
Comorbidities Other than neuro	○ None Significant	○ Impaired Ailment that is most concerning	○ Decompensated
Inhibitors Smoking, steroids, immunosuppressors	○ None	○ Prior Use	○ Current
Neuro Deficits	○ None	○ Mild-to-Moderate Sensory/motor deficits	○ Severe Paralysis, CVA contractures
Host Status:	☐ **Healthy** 7½ to 10-Pts	☐ **Problem** 3½ to 7-Pts	☐ **End-stage** 0 to 3-Pts

***Decomp'd** = Decompensated; requires tertiary care providers such has Critical Care Specialists, Cardiologists, Nephrologists, Hematologists, etc.,

Goal Score

This score quantifies the patient and/or the family's desire for limb salvage (See Table 3).

The Goal Score (GS) is obtained by summing the assessments, again on 2 to 0- point grades of: 1) Patient motivation, 2) Patient comprehension, 3) Patient compliance, 4) Care providers (e.g., self/family, nursing services, or none) and 5) Patient (or durable Power of Attorney) insight. It serves three purposes: firstly, it complements the information derived from the Wound and Wellness Scores. A second benefit of scores greater than 4-points (on the 10-point scale) is that they confirm that the patient (and/or family) is mindful of the problem, can make decisions regarding the options and can do or assist in activities of daily living and wound care.

Thirdly, this score provides criteria for how often the patient needs to be followed as an outpatient during convalescence and after the wound heals. For example, 7.5 to 10-point scores justify yearly visits to assess risk factors and appropriateness of footwear; while 3.5 to 7-point scores justify quarterly visits focusing on compliance issues such as skin care, toenail care and using protective footwear. Finally, low scores (i.e., <3.5 points) indicate that the patient needs to be checked weekly or every couple of weeks to avoid new wounds, optimize skin and toenail care, reiterate the importance of compliance with using protective foot wear (as well as nutrition, diabetes and smoking cessation management) and monitor for attenuated skin, new wounds or worrisome deformities. If a concern is raised for a new wound, immediate offloading, wound management and/or proactive surgeries need to be done.

The importance of care providers, the fourth of the five GS assessments, can be witnessed in the impact on both good initial outcomes and long-term durable results. This assessment is best provided by the patients themselves or the family and to a lesser extent, institutions, home health nurses and patient care assistants.

The Decision-Making Algorithm

By utilizing the scores generated from the LBSWS, Wellness and Goal Scores, rational decisions arise for patient management (See Figure 1).

If the LBSWS is in the transitional zone (i.e., 2.5 to 4-points) or higher and the Wellness and Goal Scores are greater than 4 points, quantifiable justification exists for doing everything possible to heal the wound and avoid leg amputations. This includes debridement, antibiotics and management of deformities. If either the Wellness or Goal Score is less than 4-points, even with a LBSWS equal to or greater than 3.5 points, palliative care should be the primary consideration. Palliative care, in this permutation, implies keeping the patient as healthy, comfortable and functional as possible without consideration for a lower limb amputation. Wound interventions would include infection source control, minimally invasive surgeries, such as toes or forefoot, utilization of wound off-loading devices and providing the simplest possible wound care. Finally, if both the Wellness and Goal Scores are less than 4-points, leg amputation is justified based on our algorithm.

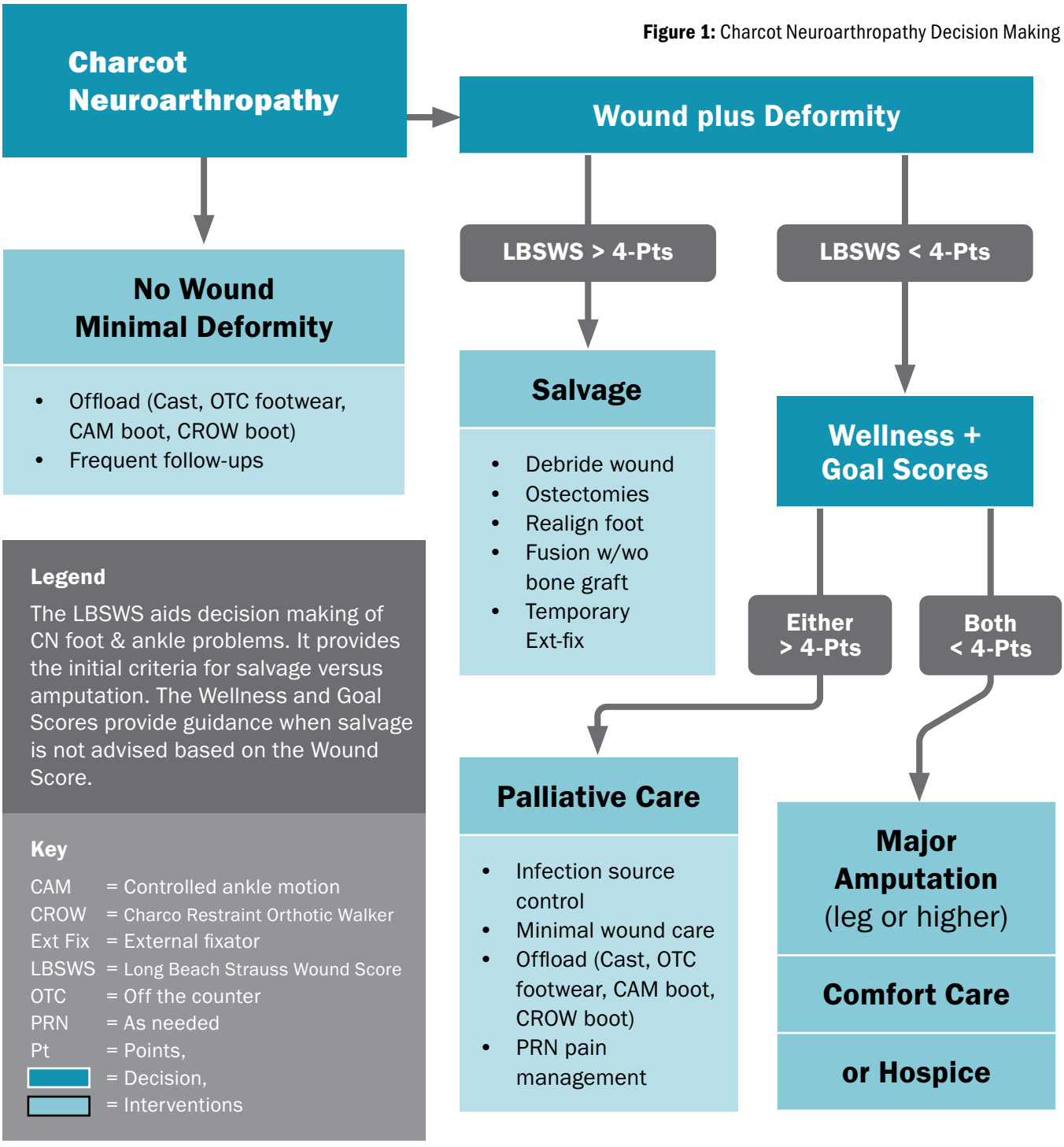
Table 3: **Goal Score**

Assessment/ Grade	Full (2-Pts)	Some (1-Pt)	None (0-Pts)
	Use half points if grades are mixed or intermediate between 2-points		
Comprehension			
Motivation			
Compliance Adherence	Consistently	To some extent	Not at all
Care/Support	Self / Family	Institution	Almost none
Insight			

Scoring:

- ☐ **7.5 to 10-Points:** Mindful (i.e., comprehension & insight) of problem and has satisfactory care/support and goals
- ☐ **3.5 to 7-Points:** Consider Wound and Wellness scores before making management decisions
- ☐ **0 to 3-points:** Comfort care, palliative care, or major amputations

Figure 1: Charcot Neuroarthropathy Decision Making



Discussion

The Long Beach Strauss Wound, Wellness, and Goal Scores provide quantifiable information for justifying limb salvage versus amputation in patients with severe Charcot neuroarthropathy deformities, with or without limb-threatening wounds. When the Wellness and Goal Scores are both less than 4-points, even if the LBSWS is in the Problem Wound range (i.e., 3.5 to 7-points) or there is no wound, but a marked deformity is present, amputation is recommended. If either are greater than 4-points, then palliative interventions, but not leg amputation, are justified.

Of course, the final decisions regarding salvage attempts versus amputation rest on the patient, family or durable Power of Attorney's decision. With quantitative information from our three user-friendly, intuitively obvious and objective grading 0 to 10- point scoring tools, rational recommendations are made for the decision-makers. We are unaware of any publications that attempt to quantify decision-making using published health status scoring systems for management recommendations of Charcot neuroarthropathy.

Limitations

This information in this paper has limitations, with the chief one being that it represents the authors' experiences, be they extensive, and of decades of observations. Secondly, other scores are available for evaluating wellness and comorbidities with no attempt being made in this paper to utilize them or make comparisons with our system to generate a Wellness Score. Thirdly, while parameters are offered for the grading of each assessment for determining the three scores, the intermediate grades (i.e., 1.5- and 0.5-points) are 'crutches' when whole number grades are mixed or in between two numbers. Fourthly, as in any biological system, outliers exist so judgment by the care provider and insight by the patient (or family) ultimately determine the decision between attempting limb salvage and leg amputation in the CN patient. Finally, the role of pain in decision-making for the CN patient is not elaborated-on. While pain is often a crucial consideration in amputation decisions in the vasculopath or patient with severe traumatic extremity injuries, it is almost never a consideration in the CN patient. This is attributed to the dense sensory neuropathy almost always present in the patient with CN.

Conclusions

The Wound, Wellness and Goal scores provide objectivity for making crucial decisions about limb salvage versus amputation for the Charcot neuroarthropathy patient. Their utilization in an algorithm approach provides understandable information to the patient (and family) for crucial CN-making decisions. Studies to evaluate these scoring tools' reliability, validity and predictability of outcomes are warranted. Our CN scoring tools are useful for comparative effectiveness research studies, since outcomes of treatment interventions become comparable in wounds with similar scores. In addition, the quantification of progress, i.e., Minimal Clinical Important Difference, is achieved with serial LBSWSs in conjunction with the use of our algorithm for the Charcot neuroarthropathy.

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Implementing The WIfI-Guided Approach To Limb Preservation: A Practical Framework For The Multidisciplinary Team

George Theodorakopoulos BSc RN BSc Podiatry MSc MBA MSc MSc(c) and **David G Armstrong** DPM MD PhD

Abstract: Diabetic foot ulcers (DFUs) remain a leading cause of hospital admission, limb loss and reduced life expectancy in patients with diabetes, often carrying a prognosis as severe as many common cancers. Despite established guidelines, the complexity of managing these wounds—compounded by neuropathy, ischemia and infection—can lead to fragmented care and delayed interventions. This article proposes a practical framework for limb preservation organized around the Society for Vascular Surgery's WIfI (Wound, Ischemia and foot Infection) classification system. We define a WIfI-guided approach not just as a staging tool, but as a clinical mindset that dictates urgency and prioritizes three core domains: offloading, debridement/wound hygiene and perfusion optimization. By mapping standard interventions—such as non-removable offloading devices and point-of-care fluorescence imaging—to the WIfI components, clinicians can better recognize early signs of deterioration. This framework emphasizes that advanced therapies should only be introduced once this foundational care is optimized. Ultimately, utilizing WIfI-guided triage helps multidisciplinary teams communicate more effectively, react faster to changes in the wound bed and move toward a more proactive model of amputation prevention.

Key words: *diabetic foot ulcer, limb preservation, WIfI classification, multidisciplinary care*

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Diabetic foot ulcers (DFUs) are among the most serious complications of diabetes. Global point prevalence among people with diabetes is around 6.3%,[1] and major reviews estimate that about 19–34% of people with diabetes will develop a foot ulcer at some point in their lives.[2] Once a DFU develops, outcomes can be severe. Long-term survival after ulceration or amputation can be poor, sometimes comparable to outcomes seen in major cancers.[3] DFUs also recur frequently, creating an ongoing cycle of breakdown and risk to both limb function and limb survival.[2,4] DFUs also place a major burden on patients and health systems. People with DFUs often require more clinic visits, hospital care, surgery and long treatment courses than people with diabetes without ulcers, and costs increase further when infection or amputation occurs.[5-7] The impact is not only financial. DFUs can reduce mobility and independence and cause ongoing stress; depression is common in this group.[8] Global analyses also highlight substantial geographic and sociodemographic disparities in DFU burden.[9]

Most DFUs develop when several problems happen together. Neuropathy reduces awareness of pain and pressure, so rubbing, minor trauma or poor-fitting footwear may not be noticed.[10] Structural problems such as clawed toes, bony prominences and Charcot-related deformity can increase local pressure and promote ulcer formation.[10] Many patients also have peripheral artery disease (PAD), which reduces blood flow and is linked with delayed healing and higher risk of major amputation.[10] Outcomes

also vary between countries and health systems, likely reflecting differences in prevention programmes, access to vascular assessment and how diabetic foot services are organised.[9] Infection often marks a turning point in the course of a DFU. Diabetic foot infection is a leading reason for hospital admission and a major contributor to amputation risk.[11] In chronic wounds, bacteria can persist as organised communities (biofilm), which may sustain inflammation and delay healing.[12,13] Studies in DFUs describe mixed organisms, including anaerobes and resistant strains, that can contribute to persistent inflammation and poorer response to treatment.[14,15] Culture results from superficial swabs may not reflect deeper infection, especially when samples are taken before proper debridement.[14,15]

Guidelines recommend structured multidisciplinary care, including offloading, repeated debridement, prompt infection management and perfusion assessment with revascularisation when indicated.[10,16-19]

The IWGDF 2023 Healing Guideline Update also stresses that advanced therapies should be considered only after good basic care has been delivered.[19] Follow-up and prevention are essential, especially for people in remission after healing.[20] The Toe and Flow model—developed and advanced by David G. Armstrong, Lee C. Rogers and colleagues—was pivotal because it translated limb preservation into a practical, team-based pathway rather than a series of siloed consultations.[21] Its core insight was that ulcer outcomes are rarely determined by toe (local wound care) or flow (perfusion) alone; they depend on coordinated, time-sensitive execution of both. In doing so, it helped crystallize the modern limb-salvage clinic mindset: rapid identification of ischemia, early vascular engagement when needed and disciplined high-quality wound care in parallel. It also provided a common language that aligned podiatry, vascular surgery, infectious diseases and wound teams around shared goals and handoffs. Our WIfI-guided approach builds directly on this foundation by adding a standardized threat-stratification framework to set urgency and sequence the same core actions—offload, debride and perfuse—more consistently across settings.[21] Building on this practical model, we organise limb preservation using the WIfI (Wound, Ischemia and foot Infection) way of thinking, delivered through three core domains: offloading, debridement and wound hygiene and perfusion assessment with optimisation.[22]

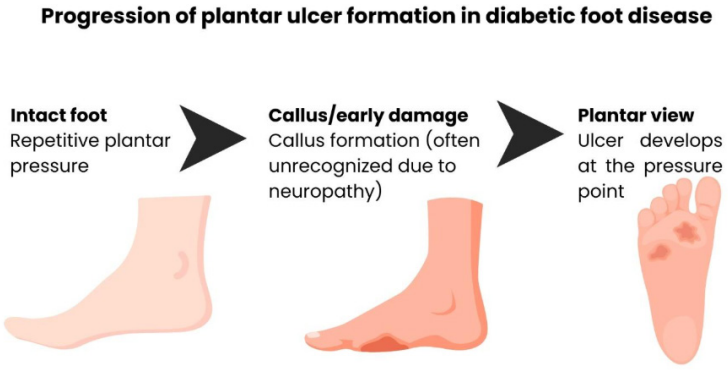

Figure 1: Progression of plantar ulcer formation in diabetic foot disease (pathways leading to DFU development).[10]

What We Mean By WIfI-Guided Limb Preservation

WIfI is a simple way to look at a threatened limb by focusing on three things: the *Wound* (how much tissue is involved), *Ischemia* (how poor the blood flow is) and *foot Infection* (how severe infection is).[22] A 'WIfI-guided' approach means we use this mindset to set urgency and priorities. If any one of the three gets worse, the plan should escalate—often faster than a routine follow-up schedule. In day-to-day practice, many problems happen between visits: patients may not wear the offloading device consistently, dressings may get wet, redness may spread or swelling may increase. Between visits, brief phone/video check-ins, supported by structured wound photos, can help teams catch early deterioration and trigger earlier in-person review when needed. Telemonitoring appears feasible for selected patients and may achieve healing outcomes comparable to standard follow-up in some settings, but it should complement—not replace—hands-on assessment and objective evaluation of perfusion and infection.[23]

The Three Core Domains

The three domains are:

- *Wound & Offloading:* protect the wound and reduce pressure and shear.
- *Debride and Clean:* improve the wound bed and control surface contamination/biofilm; address infection promptly when present.
- *Perfuse:* assess ischemia and restore blood supply when it is limiting healing.[22]

In most patients, offloading and repeated debridement are needed from the start to manage the wound component. Perfusion assessment and revascularisation become critical when ischemia is present or when healing stalls.

Offload: Reducing Mechanical Stress

Even when blood flow is adequate, DFUs may not heal if they are exposed to repeated pressure and shear. Neuropathy, deformity and mechanical stress are key contributors to DFU development and recurrence.[2,10] When protective sensation is lost, patients may continue walking on the ulcer without realising the damage.[2] High plantar pressure under metatarsal heads, or in the midfoot with Charcot deformity, can maintain a hostile environment and prevent healing.[10] For neuropathic plantar ulcers, guidelines recommend non-removable knee-high devices as first choice.[17] When non-removable devices are not suitable—because of infection, severe PAD, or balance concerns—removable knee-high walkers can be used, but outcomes depend on how consistently they are worn.[17] Other options (ankle-high devices, custom footwear) are generally less reliable for active plantar ulcers.[17] For ulcers on the dorsum, heel or sides of the foot, offloading is usually more local and depends on location and cause.[17] After healing, preventive footwear is essential to reduce recurrence.[16]

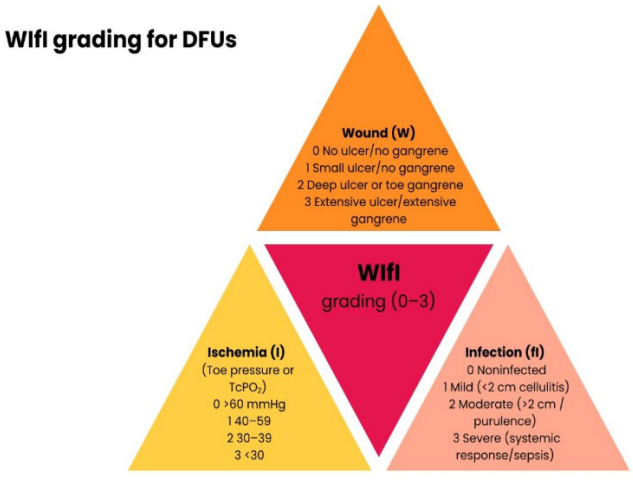

Figure 2: WIfI grading for diabetic foot ulcers (Wound, Ischemia, and foot Infection components; 0–3 severity scale).[22]

Debridement And Wound Hygiene: Managing Wound (W) And Foot Infection (fI)

Many DFUs stall because of slough, callus, and biofilm. Regular debridement removes devitalised tissue, reduces bioburden and supports granulation.[10] In a comparative study by Nube and colleagues, weekly debridement did not clearly outperform debridement every two weeks when care was structured and wounds were reassessed regularly; however, the study was underpowered, so equivalence should be interpreted cautiously.[24] Superficial swabs taken before debridement may miss deeper pathogens, particularly when biofilm and anaerobes are present.[10,14,15] Biofilm consists of mixed bacterial communities within a protective matrix.[12-15] Chronic DFUs may show increased matrix-degrading enzymes (including MMP-9) with relatively reduced inhibitor activity (TIMPs), sustaining inflammation and impairing healing.[25,26] Portable fluorescence imaging (F-I) can identify clinically meaningful bacterial burden (≥10^4 CFU/g) in wounds that may appear uninfected, helping target wound hygiene and debridement. It detects endogenous fluorophores associated with bacterial burden and has supported the concept of chronic inhibitory bacterial load (CIBL)—high bacterial load that suppresses healing without overt infection. Clinical studies suggest F-I-guided care can improve detection and guide more appropriate debridement, with better healing trajectories when positive findings prompt action.[27-29] Wound hygiene should include cleansing and appropriate antiseptics to slow biofilm re-formation.[14,15]

In non-infected, slow-progressing ulcers with heavy exudate, protease-modulating strategies may help protect the wound environment.[19,26]

Perfusion Assessment: Managing Ischemia (I)

A core part of WIfI thinking is recognising the ischemia component. Peripheral artery disease (PAD) is associated with slow healing and major amputation.[10,18] Outcomes are particularly poor in chronic limb-threatening ischaemia.[3] Clinical examination can miss disease in diabetes due to arterial calcification and altered hemodynamics.[10,18] Non-invasive tests (ABI/TBI) are recommended to detect reduced perfusion.[18] Vascular imaging is considered if findings suggest ischaemia or if an ulcer fails to improve despite good care.[18] Guidance advises prompt vascular specialist assessment for DFUs with limb-threatening ischaemia because delays increase the risk of major amputation and death.[18] Revascularisation can make offloading and wound care more effective, and guidelines recommend improving blood flow before escalating advanced wound therapies.[18,19]

Multidisciplinary Care And Reassessment

This framework works best when the team is coordinated. If a DFU is not progressing, reassessment should be routine: check offloading fit/adherence, repeat debridement, reassess infection, and re-check ischemia.

Advanced Therapies After Foundational Care Is Optimised

Advanced interventions should be considered only after standard care is fully optimised.[19] Negative-pressure wound therapy may help in selected postoperative wounds but is not recommended over standard care in non-surgical DFUs.[19,30,31] Protease-modulating dressings such as collagen-based products may help in selected wounds when standard care is optimised.[32,33] Syntheses of randomised evidence support NPWT and collagen/ORC in appropriately selected DFUs, but the benefits depend on wound type and context.[34,35] The key point is that these therapies sit on top of the basics: offloading, debridement/wound hygiene and perfusion optimisation.[10,17-19,30-35]

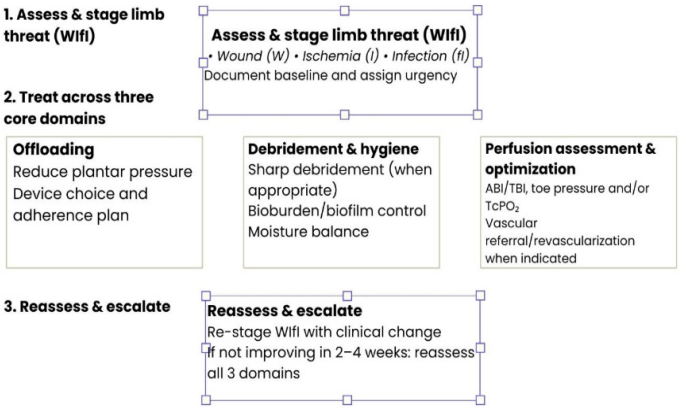

Figure 3: Integrated management pathway for active diabetic foot complications using a WIfI-guided approach.[10,22]

Conclusion

A practical way to organise limb preservation is to keep focus on WIfI: the Wound, Ischemia and foot Infection components.[22] In daily practice, that translates into three repeatable domains—offloading, debridement/wound hygiene and perfusion assessment/optimisation—with escalation when any WIfI component worsens. Used this way, WIfI helps clinicians set priorities, communicate clearly within the team and encourages them to act sooner when the limb is becoming more threatened. Given the central role of biofilm in chronic DFUs, ongoing attention to wound hygiene and infection control remains essential even as advanced therapies evolve.[36]

Abbreviations

ABI – Ankle–Brachial Index
CFU – Colony-Forming Units (in >10 CFU/g)
CIBL – Chronic Inhibitory Bacterial Load
CLTI – Chronic Limb-Threatening Ischemia
CSWD – Conservative Sharp Wound Debridement
CTA – Computed Tomographic Angiography
DFU – Diabetic Foot Ulcer
DFUs – Diabetic Foot Ulcers
ECM – Extracellular Matrix
FI – Fluorescence Imaging
IWGDF – International Working Group on the Diabetic Foot
MDT – Multidisciplinary Team
MMP-9 – Matrix Metalloproteinase-9
MMPs – Matrix Metalloproteinases
MRA – Magnetic Resonance Angiography
NPWT – Negative-Pressure Wound Therapy
ORC – Oxidized Regenerated Cellulose (as in collagen/ORC dressings)
PAD – Peripheral Artery Disease
RCT – Randomized Controlled Trial
TBI – Toe–Brachial Index
TIMP / TIMPs – Tissue Inhibitors of Metalloproteinases
WIfI – Wound, Ischemia, and foot Infection (SVS threatened limb classification)

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The Three-Minute Diabetic Foot Exam: A Simple Intervention with the Power to Save Limbs

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Abstract: Diabetic foot complications remain one of the leading causes of non-traumatic, lower-extremity amputation worldwide. Despite new innovations in wound care, vascular intervention and limb salvage techniques, far too many amputations are preceded by missed opportunities for early detection. This article presents the 3-Minute Diabetic Foot Exam, a structured three-minute commitment to assessment and patient education with the potential to shift care from reactive intervention to proactive preservation.

Key words: *diabetic foot complications, lower-extremity amputation, prevention, limb salvage, assessment, preservation*

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Diabetic foot complications remain one of the leading causes of non-traumatic, lower-extremity amputation worldwide.[1,2] Despite rapid development of new innovations in wound care, vascular intervention and limb salvage techniques, far too many amputations are preceded by missed opportunities for early detection. Peripheral neuropathy, ischemia and structural foot changes often develop silently, placing patients at risk long before a wound appears.[3]

To address this gap, ALPS (American Society of Limb Preservation) Founding President Dr. David G. Armstrong and ALPS Founding Clinical Chair Dr. Joseph L. Mills, among others, developed the *3-Minute Diabetic Foot Exam* as a practical assessment tool.[4]

Building on this work, ALPS developed a video campaign to support the dissemination and consistent implementation of this exam in clinical practice.

The 3-Minute Diabetic Foot Exam Video can be viewed here.

Designed For Broad Use

A defining feature of the 3-Minute Diabetic Foot Exam is its accessibility. Designed for broad use, anyone can perform the exam. While grounded in evidence-based principles of diabetic foot assessment, the exam is intentionally designed to be performed by a wide audience. This multi-specialty approach includes: physicians, nurses, podiatrists, vascular specialists, allied health professionals, community health workers, caregivers and family members. Utilization of this exam by a broad and diverse group of caregivers is intended to avoid missed opportunities for identifying and preventing non-traumatic amputations.

The exam focuses on three essential components:[4]

- **What to Ask:** Prior foot wounds or amputations, neuropathic symptoms, glycemic control, smoking history and prior vascular procedures.
- **What to Look For**: Skin breakdown, callus formation, deformity, signs of infection, loss of protective sensation and indicators of impaired perfusion (e.g., pulse palpation, hair growth assessment, temperature differentials).

- **What to Teach:** Daily self-inspection, appropriate footwear and early reporting of changes.

By prioritizing observation, touch and patient engagement rather than specialized equipment, the exam removes common barriers to routine screening and empowers non-specialists to recognize when escalation of care is needed.[4] A simplified visual overview of the complete 3-Minute Foot Exam is provided in Figure 1. The full clinical workflow, including the downloadable and printable screening tool, is available on the ALPS website for easy integration into routine practice.

Figure 1: 3-Minute Diabetic Foot Exam Overview

Evidence-Based Foundations And Expert Leadership

The 3-Minute Diabetic Foot Exam Video builds upon foundational work in diabetic limb preservation and responds directly to limitations identified in existing daily practice and published clinical guidelines. In response to the need for more consistent foot examinations, an American Diabetes Association (ADA) task force led by Dr. Armstrong and Dr. Boulton developed the *Comprehensive Foot Examination and Risk Assessment*[5] in 2008, which established the standard for detailed lower-limb evaluation by specialists.[4] The comprehensive exam has been in existence for nearly two decades; the 3-minute version was developed to make it implementable on a scale. While the ADA framework remains essential for specialty care, it was not designed for broader implementation across all practice settings, particularly primary care, where time constraints, limited access to specialized equipment and variable training pose significant barriers.[4]

To close this gap, the 3-Minute Diabetic Foot Exam demonstrates that a structured, time-efficient approach can reliably identify patients at risk for ulceration and amputation in overextended or under-resourced clinical environments.[4] Dr. Armstrong, a leader in diabetic foot research and Founding President of ALPS, has long emphasized that most amputations are preceded by identifiable warning signs that often go unrecognized by patients, particularly in those with neuropathy.[3] He has therefore described diabetic foot ulcers as a "silent, sinister syndrome".[3] The exam reinforces this principle, highlighting how systematic screening—even when brief—can meaningfully alter patient trajectories towards functional limb preservation. Similarly, Dr. Mills, Founding Scientific Chair of ALPS, co-developed the WIfI classification system[6] which stratifies limb threat severity and guides treatment urgency. [Editor's note: for more information on the WIfI classification system, see article on pgs. 54-59.] Comprehensive diabetic foot assessment frameworks underscore the importance of evaluating neuropathy, vascular status and structural deformity together.[4]

These core elements are embedded in the 3-Minute Diabetic Foot Exam and align with international best practice recommendations, while enabling wider implementation across frontline care settings.

Why Three Minutes Matter In Limb Salvage

Lack of time is often cited as a barrier to performing screening or preventive foot exams. Ironically, the absence of screening frequently leads to downstream complications that demand far more time, resources and cost, including hospitalization, revascularization, prolonged wound care and, ultimately, major limb amputation.[1-5] The 3-Minute Diabetic Foot Exam reframes prevention in a way that is both feasible and scalable, embedding risk identification into routine clinical workflows rather than relegating it to specialty settings.

The clinical impact of early podiatric and multidisciplinary team evaluation is real and not only theoretical; it is quantifiable. A systematic review and meta-analysis by Blanchette et al. demonstrated that multidisciplinary care teams including podiatry were associated with a 31% relative risk reduction in any amputation and a 55% relative risk reduction in major amputation.[7] Similarly, Gibson et al. reported that podiatric care delivered prior to ulcer development was associated with significantly reduced limb loss and fewer hospitalizations among patients with diabetes.[8] More recently, Luu et al. showed that Medicaid beneficiaries living in US states with podiatric coverage had a 48% lower risk of major amputation compared to those without such access.[9] Together, these data demonstrate that systematic foot evaluation and early intervention materially improve outcomes.

In patients with peripheral neuropathy, pain may be absent even in the presence of advanced pathology. As a result, reliance on symptoms alone is insufficient. Structured visual inspection and sensory testing become essential tools for identifying pre-ulcerative lesions, structural deformities and perfusion deficits before tissue breakdown occurs. The brevity of the *3*-minute Foot Exam is precisely its strength; it lowers the threshold for consistent implementation while preserving diagnostic yield.

In addition, screening is not solely diagnostic; it is educational. When paired with focused counseling, the exam reinforces patient engagement. Teaching patients and families what 'normal' looks like, and what it does not, improves vigilance between visits and promotes earlier presentation when changes arise. This shared awareness transforms prevention from a clinician-dependent act into a continuous partnership.

For too long, the field of limb preservation has relied on technological innovations as a means of reversing the rise of non-traumatic amputations. It is time for the focus to shift to the foundational tenets of risk factor identification and management, before defaulting to expensive and often inaccessible new technologies.

Strengthening Multidisciplinary Pathways

Routine use of the 3-Minute Diabetic Foot Exam supports earlier referral and more effective multidisciplinary care. Primary care and community-based clinicians often serve as the first point of contact for people with diabetes. By identifying risk early, providers can initiate timely referral to podiatry, vascular surgery, wound care, endocrinology or specialized limb preservation teams.[1-5] This approach aligns with contemporary limb salvage models that emphasize coordination across disciplines and care settings. Early detection does not replace advanced therapies; it enables them to be used when they are most effective. The routine performance of a foot examination is just as critical as the new limb-preserving technologies.

A Call To Action

The ALPS 3-Minute Diabetic Foot Exam video represents more than an educational resource; it is a call to normalize routine foot screening for every person living with diabetes. The questionnaire, instructional video, and accompanying clinical materials are freely accessible through the ALPS website, ensuring broad and equitable access. Its simplicity is its strength. Designed for scalability, the exam can be seamlessly integrated into outpatient clinics, hospital systems, community health initiatives and even home-based care environments.

By lowering the barrier to consistent screening, the tool empowers clinicians, caregivers and patients alike, to participate actively in prevention. Limb loss is not an inevitable consequence of diabetes. A structured three-minute commitment to assessment and patient education has the potential to shift care from reactive intervention to proactive preservation, changing trajectories from inevitable amputation to prolonged, functional limb salvage.

Further Information

- ALPS 3-Minute Diabetic Foot Exam: https://limbpreservationsociety.org/professional-resources/3-minute-diabetic-foot-exam/
- ALPS 3-Minute Diabetic Foot Exam Form: https://limbpreservationsociety.org/wp-content/uploads/2026/02/3-min-foot-exam-form.pdf
- ALPS: https://limbpreservationsociety.org/
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A Conceptual Amputation Prevention Protocol For Diabetes-Related Foot Disease In South Africa: Insights From A Regional Public Hospital

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Abstract: Diabetes-related foot disease (DFD) remains one of the most common causes of non-traumatic lower-limb amputations worldwide, with the most significant impact in low- and middle-income countries (LMICs). In South Africa, rising diabetes rates, coupled with strained health systems, hinder early detection, coordinated care and limb preservation. Although global research confirms that many diabetes-related amputations can be prevented, public health-care settings continue to experience high rates of avoidable limb loss. This article presents a conceptual Amputation Prevention Protocol (APP), developed from practical experience in a public regional hospital in Gauteng Province, South Africa and informed by global and LMIC-specific literature reviews. Rather than prescribing a rigid clinical pathway, the APP serves as a flexible decision-making and coordination tool to address key systemic issues, including the late detection of peripheral artery disease (PAD), fragmented referral processes and delayed involvement of multidisciplinary teams. This manuscript outlines the APP's rationale, core components and intended use. It promotes early risk screening, accessible vascular assessments, podiatry-led coordination and team-based care, all tailored to resource-limited settings.

Key words: *diabetic foot disease, peripheral artery disease, amputation prevention, limb preservation, South Africa, regional hospital, low- and middle-income countries, public-sector podiatry*

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Diabetes mellitus (DM) has become one of the most significant public health concerns of the 21st century. According to the International Diabetes Federation (IDF), approximately 589 million adults worldwide will have diabetes in 2024, accounting for 11.1% of the global adult population. This number is projected to rise sharply, reaching 853 million by 2050.[1] Notably, over 80% of individuals with diabetes reside in low- and middle-income countries (LMICs), where health-care systems often struggle with staff shortages, limited diagnostic tools and poorly coordinated referral systems.[1,2]

Among the many complications of diabetes, diabetes-related foot disease (DFD) is particularly severe. The lifetime risk of developing a diabetic foot ulcer (DFU) is estimated to be up to 34%, and diabetes is responsible for 40–60% of all non-traumatic lower-limb amputations globally.[3-5] Alarmingly, five-year survival rates after major lower-limb amputation are similar to, or worse than, those for some cancers.[6] Beyond the risk of death, amputation leads to serious consequences, including physical disability, emotional distress, caregiving demands and high financial costs for both families and the health-care system.

Encouragingly, a significant proportion of amputations can be prevented through timely intervention. Studies have shown that up to 85% of diabetes-related amputations are avoidable

with timely risk assessment, proper foot care and coordinated, team-based management.[7-9] Despite the availability of international guidelines and growing awareness of effective practices, unnecessary amputations remain common, particularly in public health systems and LMIC settings. This ongoing gap highlights the need to move beyond merely sharing clinical guidelines and instead focus on building health-care system frameworks that promote timely, equitable and well-integrated care.

Global, Regional And South African Burden Of Diabetes-Related Foot Disease

Worldwide, diabetes-related foot disease (DFD) significantly adds to the burden of disease, contributing to disability, health-care costs and lost productivity. In high-income countries, advances in foot care and vascular interventions have reduced amputation rates. However, these improvements have not reached many LMICs, where challenges such as late presentation, limited access to specialised care and inconsistent screening practices remain widespread.[7,10]

South Africa reflects many of these issues. The national prevalence of diabetes has risen steadily, primarily due to population ageing, increasing urbanization and persistent social inequalities. In the public health sector, patients often present to hospitals with advanced foot ulcers, complicated by infection or reduced blood flow. These delays are frequently the result of late referrals from primary care, limited access to vascular testing and poor coordination across different areas of the health-care system, all of which increase the likelihood of amputation.

Peripheral Artery Disease And Diagnostic Blind Spots In Diabetes

Peripheral artery disease (PAD) plays a crucial role in determining the outcomes of diabetes-related foot disease. Among individuals with diabetes, PAD affects approximately 20% to 40% of individuals and the risk increases with age, longer duration of diabetes and the presence of other health conditions.[11] When PAD occurs alongside nerve damage (neuropathy), it severely affects the body's ability to heal wounds and dramatically increases the risk of infection and major amputation.

The ankle-brachial pressure index (ABPI) is a standard, inexpensive and easy-to-use tool for detecting PAD. However, in individuals with diabetes, arterial calcification can make the arteries stiff and difficult to compress, often producing falsely normal or elevated ABPI readings.[12,13] This can lead to missed diagnoses of serious blood flow problems and delays in receiving appropriate care.

To improve detection, other tests, such as toe systolic pressure and the toe-brachial index (TBI), offer greater sensitivity in identifying reduced blood flow in the feet. These recommendations align with international clinical guidelines.[14,15] Unfortunately, access to these additional tools is limited in many public-sector facilities and they are not routinely used. As a result, essential signs of poor circulation may be overlooked, creating serious diagnostic challenges.

Table 1: Global, Low- And Middle-Income Countries (LMICs) And South African Burden Of Diabetes-Related Foot Disease

Indicator	Global	LMICs	South Africa (Public Sector)
Adults living with diabetes	589 million (2024)	>80% of global burden	Rising prevalence
Lifetime DFU risk	Up to 34%	Higher due to late presentation	High
Diabetes-related amputations	40–60% of non-traumatic	Disproportionately high	High
Preventable amputations	Up to 85%	Under-realised	Under-realised
Post-amputation mortality	50–70% at 5 years	Often higher	High

Sources: IDF [1], Armstrong et al.[4], Abbas ZG et al.

Limitations Of PAD Diagnostic Technologies In Resource-Constrained Settings

Systematic reviews demonstrate that while automated ankle-brachial index devices improve the feasibility and scalability of vascular screening in primary care and low-resource environments, their diagnostic sensitivity is reduced in patients with diabetes and medial arterial calcification when compared with Doppler-derived measurements and toe pressure assessment.[20,21] This highlights the need to interpret test results within a broader clinical context rather than rely on a single measurement to guide care.

In many low- and middle-income countries, the problem extends beyond access to the right technology. Even the most advanced diagnostic tools must be integrated into a well-coordinated system that ensures timely referrals, collaborative team reviews and early intervention. Without these system-level supports, even the best diagnostic devices are unlikely to significantly reduce amputation rates.

Rationale For A Coordinated Amputation Prevention Approach

There is strong global guidance on preventing and managing diabetes-related foot disease, with the International Working Group on Diabetic Foot (IWGDF) being a leading voice in setting standards. However, these guidelines are not consistently applied, particularly in public health systems and LMICs.[14,17] Common challenges include shortages of trained staff, limited access to education and upskilling, poor communication among health professionals and a lack of coordination models tailored to the local context.

Research shows that coordinated, team-based care is far more effective in preventing amputations than isolated clinical actions. Multidisciplinary foot care programs that integrate screening, diagnosis, treatment and follow-up have repeatedly demonstrated better outcomes.[7,18] For example, the 'Step-by-Step' program has led to significant reductions in amputation rates when applied within structured care pathways in LMICs.[9]

These insights highlight the urgent need for a unifying coordination framework that can streamline screening, vascular assessment, referrals and care escalation, while also being flexible enough to function in resource-limited environments.

The Amputation Prevention Protocol: A Conceptual Coordination Framework

The Amputation Prevention Protocol (APP) was introduced as a flexible, high-level framework to improve diabetic foot care in regional public hospitals. Rather than acting as a strict clinical guideline or prescribing diagnostic thresholds and treatments, the APP focuses on how care is structured, coordinated and escalated within the health-care system.

Its purpose is to address the gaps in communication, referral and early risk detection, which often contribute to avoidable limb loss. It is not meant to replace existing best practices but to strengthen how those practices are implemented in real-world, resource-limited settings.

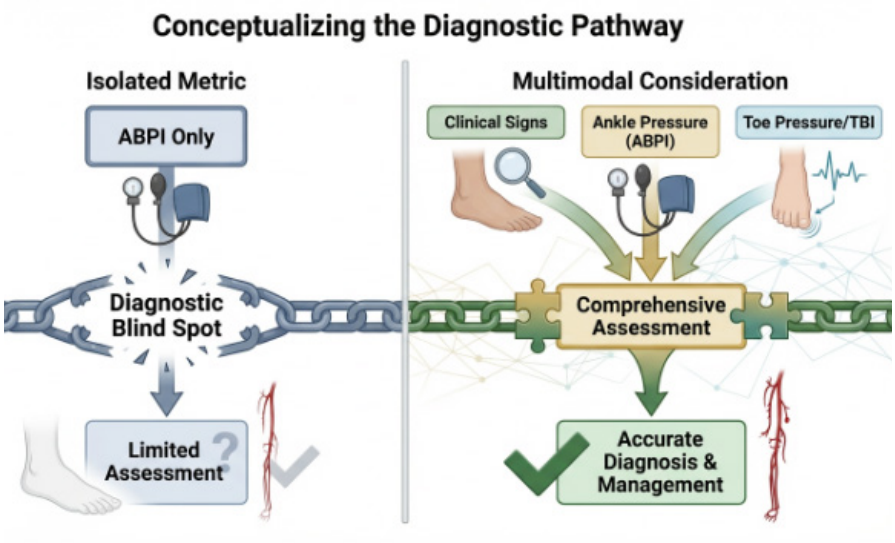

Figure 1: Conceptual Illustration of PAD Diagnostic Blind Spots in Diabetes

Key Components Of The APP Framework

Key components of the APP Framework include:

1. ***Early Risk Identification:*** Routine and structured foot screenings, including checks for peripheral artery disease (PAD), are prioritised to detect problems early.
2. ***Appropriate Vascular Assessment:*** PAD screening is built into the protocol, with the recognition that ABPI alone may not be reliable in patients with diabetes. A broader approach to vascular evaluation is therefore encouraged.
3. ***Podiatry-led Coordination***: Podiatrists play a central role in triaging patients, monitoring progress and facilitating communication across care teams.
4. ***Multidisciplinary Collaboration***: The APP promotes teamwork among nurses, primary care providers, vascular specialists, surgeons and rehabilitation professionals.
5. ***Continuous Learning and Quality Improvement:*** Regular feedback loops and audits are built to track outcomes and guide ongoing improvements in care delivery.

Scope And Intended Use Of The APP

The Amputation Prevention Protocol is shared solely as a conceptual framework. It aims to guide service planning, inform training efforts and support the phased implementation strategies. It is not a clinical practice guideline, diagnostic tool or operational protocol.

Specific thresholds, detailed procedures and implementation materials were omitted. These elements will be developed through future academic work and system-level evaluations to ensure the protocol remains evidence-based and context-appropriate.

Clinical Insight From A South African Regional Hospital

The experience at Leratong Regional Hospital in Gauteng Province, part of South Africa's public health-care system, underscores the tangible repercussions of inadequate coordination and postponed vascular evaluation in the management of diabetic foot conditions. Patients presenting with diabetic foot ulcers (DFUs) frequently arrive at advanced disease stages, thereby exemplifying systemic barriers such as insufficient screening programs, delayed health-care access and ineffective referral mechanisms.

In one illustrative case, a patient with diabetes presented with foot ulcers. An initial ankle-brachial pressure index test suggested adequate blood flow to the limb. However, a follow-up toe pressure assessment revealed significant ischaemia that had been missed. By the time the correct diagnosis was made, opportunities for earlier intervention had passed, and the tissue damage had progressed.

This case occurred before the development of the APP and became a key learning moment, prompting a reevaluation of how vascular assessments are coordinated in diabetic foot care settings.

Table 2: System Gaps And Conceptual APP Responses

Identified System Gap	Conceptual APP Response
Late PAD recognition	Prompted vascular consideration
Fragmented referrals	Coordinated MDT communication
Reactive care models	Early risk identification
Resource limitations	Scalable, low-cost focus

Figure 2: Conceptual Amputation Prevention Protocol Coordination Framework

Broader Impacts: Caregiver Burden And System Costs

The impact of major lower-limb amputation extends well beyond the physical loss of a limb. Research shows that it imposes a significant emotional and practical burden on caregivers, reduces patients' quality of life and creates lasting financial strain for individuals and families.[17] These challenges are even more severe in LMICs where access to rehabilitation services, prosthetics and social support is often limited or unavailable.

From the perspective of the health system, preventable amputations place a heavy burden on already stretched resources. They often require extended hospital stays, multiple surgical procedures and long-term care and support. This makes early prevention and coordinated care not only a medical priority, but also a necessary strategy for maintaining sustainable health-care systems.

Policy Alignment And Health-System Relevance

The Amputation Prevention Protocol closely aligns with the goals outlined in *South Africa's National Department of Health Strategic Plan for 2025–2030*. This national plan prioritizes improvements in primary health care, more efficient referral systems and the reduction of preventable illnesses and disabilities.[18]

By promoting early risk detection, timely vascular assessment and improved coordination across care levels, the APP supports key national objectives, particularly in the management of non-communicable diseases. It also contributes to broader efforts to build a more resilient and responsive public health system in the country.

Conclusion And Call To Action

When a diabetes-related amputation occurs that could have been prevented, it reflects not just a clinical shortcoming, but also a failure of the health system. Despite overwhelming evidence that many of these amputations are avoidable, public health-care systems, especially in low- and middle-income countries, still struggle with poor coordination, late diagnosis of PAD and fragmented care pathways.

Rather than adding complexity, the Amputation Prevention Protocol offers a structured yet flexible approach that prioritizes timely coordination, early risk detection and system-wide collaboration. This study lays the groundwork for improving diabetic foot care at every level of the health-care system.

Health professionals, policymakers, researchers and system leaders are encouraged to prioritize coordination science as a key component of limb preservation strategies. Strengthening podiatry-led care models, ensuring that vascular assessments are routinely included in diabetic foot care and rigorously evaluating system-wide interventions can help reduce the rate of preventable amputations.

Looking ahead, research should focus on how coordination frameworks, such as the APP, can be implemented in phases and evaluated in real-world settings. These efforts are essential to developing sustainable, context-sensitive solutions that work in both resource-limited and mainstream health-care settings.

Statement of Originality: This manuscript introduces a novel conceptual framework developed by the author, drawing on direct experience in public-sector clinical settings, academic research, and relevant global literature. The Amputation Prevention Protocol (APP) has not been previously published or implemented as a clinical pathway in the literature. All elements presented here are original and intended to stimulate academic dialogue and guide future evaluations.

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Redesigning Ankle-brachial Index Calculation For Better Wound Care: Research Shows The Way

Maryse Beaumier RN PhD

Abstract: Lower extremity wounds associated with peripheral arterial disease (PAD) and diabetes carry substantial risks of morbidity, amputation and health-care burden. Although clinical guidelines recommend the ankle-brachial index (ABI) as part of a comprehensive vascular assessment, its diagnostic accuracy is limited in patients with medial arterial calcification, commonly seen in diabetes, chronic kidney disease and advanced age. These limitations may lead to falsely normal ABI values and delayed recognition of PAD. The objective of this study was to compare standard ABI calculation with an angiosome-based ABI approach that accounts for the specific arterial supply of the wound's anatomical territory, and to determine whether this improves the accuracy and clinical relevance of ABI vascular assessment in patients with lower limb wounds. The findings support integrating angiosome-based ABI assessment into routine vascular evaluation of foot wounds.

Key words: *Lower limb wounds, diabetes, peripheral artery disease (PAD), ankle-brachial index (ABI), angiosome-based ABI, vascular assessment, limb salvage*

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Wounds represent a major public health issue with significant impacts on individuals, the environment, and health-care systems.[1-3] Wounds associated with peripheral arterial disease (PAD) and diabetes are a source of major suffering and financial burden for the patient and place a considerable burden on the patient's family, health-care providers and facilities, and society in general.[4,5] Previous reports have emphasized the synergistic effects of diabetes and PAD on amputation risk.[6-8] Patients diagnosed with both PAD and diabetes have been shown to be 7 to 15 times more likely to experience major amputation following the development of an ulcer, as compared with those without diabetes.[9,10]

Due to its numerous potential impacts on patients and its socioeconomic burden, PAD demands a responsive approach to ensure early detection.[11-13] Chronic limb-threatening ischemia (CLTI) represents the end stage of PAD and is a problem of growing prevalence, increasing health-care costs around the globe, and is associated with mortality, amputation and impaired quality of life.[12] According to the Global Vascular Guidelines on the Management of Chronic Limb-threatening Ischemia, all patients with suspected CLTI should be referred urgently to a vascular specialist.[12,14] According to Frykberg and Banks (2015), understanding and addressing the challenges inherent in the treatment of any kind of chronic wounds will lead to a better clinical outcome, resulting in improved patient quality of life and reduced health-care costs.[15]

The main recommendations for managing wounds in the lower limbs and feet have focused on two primary objectives: 1) determining if there is adequate blood flow to heal the wound and 2) assessing for signs and symptoms of peripheral arterial disease (PAD).[16,17] Multiple health-care specialists are involved in the management of PAD

and CLTI, yet lack of public awareness and the frequent failure to make an early diagnosis continue to be significant obstacles to effective treatment.[12] According to the existing literature, non-invasive instruments are available in clinical services to assess arterial vascularization. The arteriobrachial index (ABI), arterial waveforms, toe pressure, and transcutaneous oximetry are the most widely recognized. Other vascular examinations, such as Doppler ultrasound, computed tomography, angiography (CT angiography) and arteriographic resonance imaging (ART), are used for a more anatomical descriptive evaluation of the arterial tree but primarily in the vascular laboratory, as is contrast angiography, which is also an invasive procedure.[18,19] The chapter on Prevention and Management of Peripheral Arterial Ulcers in Wounds Canada's *Best Practice Recommendations For Skin Health And Wound Management 2025* provides a guide to these non-invasive tests.[17]

Current clinical guidelines recommend performing a comprehensive vascular assessment of lower limbs with the ABI in patients with a lower limb wound.[4,5,11,17] A literature review by Dachun et al. (2010) acknowledges a high level of specificity for PAD (83.3–99.00%) for an ABI ≤ 0.90 in cases of more than 50% arterial stenosis in the lower limbs, but sensitivity levels of 15–79% for ABI > 0.90, with sensitivity being lower in the elderly and those with diabetes.[17] Variations in values may also stem from a lack of measurement standards and the different methods used in calculating the index.[21,22] Furthermore, the clinician's lack of experience, the type of Doppler device used and the technique for taking pressure measurements (with or without prior rest, head elevated or not, cuff size appropriate for limb circumference) are all parameters that can explain fluctuations in the data. Other major barriers to the use of ABI measurements are the availability of Doppler equipment, the time required to perform the examination and adequate training[23] and the ABI calculations themselves. A few studies already confirm many other methods for ABI calculations.[21,24-29] The most significant limitation of ABI is the potential incompressibility of calcified distal arteries in individuals with diabetes.[17,30,31]

This study is based on secondary data from a larger study with three other non-invasive instruments to detect PAD as Doppler arterial waveforms, toe pressure by plethysmography (manual) and laser.[32] These various criterion measurements are recognized in literature as theoretically competent for measuring arterial vascularization in the lower limbs to detect PAD. To ensure their convergence in the clinical trial, a table of their respective correlations was compiled during the study (Table 1).

Table 1: Correlations of vascular instrument

	Posterior tibialis monophasic waveforms	Dorsalis pedis monophasic waveforms	ABI < 0,5 and > 1,3	Manual TBP < 30 mmHg, ≥100mmHg	Laser TBP < 30 mmHg, ≥100mmHg
Posterior tibialis (PT) monophasic waveforms < 30 mmHg, ≥100mmHg	—	0,629**	0,328**	-0,223**	-0,101
Dorsalis pedis (DP) monophasic waveforms < 30 mmHg, ≥100mmHg	0,629**	—	0,377**	-0,304**	-0,195**
ABI < 0,5 and > 1,3	0,328**	0,377**	—	0,075	-0,049
Manual TBP	-0,223**	-0,304**	0,075	—	0,644**
Laser TBP	-0,101	-0,195**	-0,049	0,644**	—
*Pearson's R type correlation, ** p < 0.01					

From Beaumier, M. (2019). Élaboration et validation d'une grille prédictive de la vascularisation artérielle insuffisante à une plaie au membre inférieur. [Development and validation of a predictive grid of insufficient arterial blood supply to a lower limb wound.] Sous la direction de Gilles Bronchti, PhD et Louis Laurencelle, PhD Université de Montréal]. Québec, Canada. http://depot-e.uqtr.ca/8799/1/032273565.pdf

Contrary to expectations and the findings of the exhaustive literature review, negative correlation coefficients emerged, indicating a lack of convergence among the criterion measurements to explain PAD in the lower limb.[32] A negative correlation between two variables indicates that the values of one variable tend to increase when those of the other decrease. More specifically, this means that when monophasic dorsalis pedis artery wave measurement shows PAD, manual pressure measurement might show normal arterial vascularization.

Furthermore, we observed that the ABI values do not correlate with the toe pressure values. This could indicate that these two instruments measure two different things. However, the validity of ABI is known to be suboptimal in the presence of medial wall calcification of the main arteries, especially in the population with diabetes.[5,30,33] Moreover, noncompressible arteries may affect the ABI by providing falsely elevated or normal values in patients with diabetes, chronic renal insufficiency, or advanced age,[12,14] within conclusive, distorted results, or potentially overestimating the actual vascular flow. Inconclusive, distorted results and potentially overestimation of the actual vascular flow is often seen in individuals with diabetes,[12,14, 34] a population peculiarly affected by PAD.[35-37]

These results have raised significant questions about the validity of the results and interpretation for the ABI, its calculation method and the consideration of the foot's angiosomes. Angiosomes must be considered for all these non-invasive tests; otherwise, the interpretation of the vascular evaluation could be distorted.[38-40] An angiosome is a three-dimensional block of anatomical tissue supplied by a specific artery. The angiosome concept has gained popularity as an approach to improving limb recovery, in which target vessels for revascularization are chosen based on the angiosome containing the wound.[18] Although arterial connections exist between angiosomes, the angiosome theory posits that superior outcomes can be achieved by revascularizing the vessel that directly supplies an angiosome around tissue loss, rather than relying on indirect flow from arteries supplying adjacent angiosomes.[41] Neville's study retrospectively examined 52 incurable wounds in patients who had undergone bypass surgery and found that indirectly revascularized wounds were amputated in 38% of cases, compared to 9% of cases where the angiosome containing the wound was directly revascularized. Figure 1 shows the foot's angiosomes.

However, we know that ABI is widely used in our health-care organizations, so it becomes essential to optimize its measurement and interpretation. This study aims to highlight differences in ABI calculations and interpretations based on wound location and the foot's angiosome, enabling safe interpretation of results in the presence of PAD or CLTI. Ultimately, this study would help clinicians select the most appropriate ABI result for the clinical decision regarding the wound.

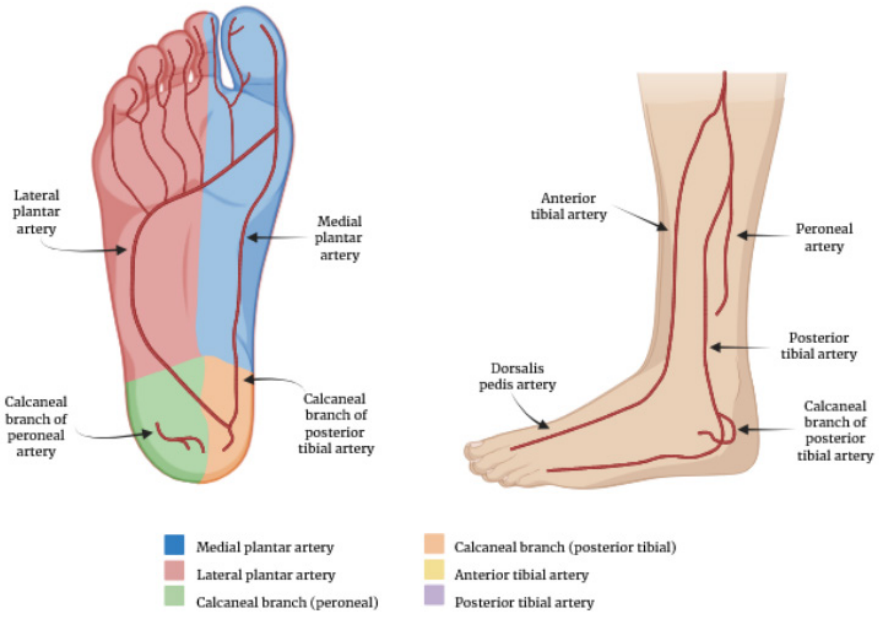

Figure 1: Anatomical distribution of the angiosomes of the foot and lower leg
Source: Created in BioRender. Green J. (https://BioRender.com/l73h427) is licensed under CC BY 4.0.

Methods

For this secondary analysis of a prospective population study from a doctoral research,[33] 108 ambulatory patients aged over 18 years and having at least one lower limb wound were recruited between May and August 2017 by convenience sampling technique at the Complex Wound Care Clinic, a Canadian university-affiliated regional hospital clinic. Institutional and University Ethics Board approvals (CER-17-235-10.02) were obtained for this study. According to the study protocol, written informed consent was obtained and documented from every patient retained. Patients were included if they presented with any kinds of lower limb wounds without regard to any diagnosis of chronic kidney disease, diabetes, PAD or CLTI. Exclusion criteria were having any condition preventing the ability to give proper consent and having received previous hyperbaric oxygen therapy.

Devices used for systolic blood pressure included a Welch Allyn sphygmomanometer with an adult cuff for arms with a circumference between 25 cm and 34 cm, or a large adult cuff for arms with a circumference greater than 34 cm up to a maximum of 38 cm. For ABI values, Huntleigh Doppler DMX Digital Doppler with Waveform (Arjo Inc., Addison IL) was used with a 8mHZ probe (See Figure 2). ABI values were obtained for every dorsal pedis (DP) and posterior tibial artery (PTA) of both feet using the same manual sphygmomanometer.

Figure 2: Posterior tibial artery (PTA) and Dorsal pedis (DP) systolic blood pressure. Photos used with permission of Maryse Beaumier.

For this study, the reference values for ABI were the results of a literature review. Articles in French and English were identified in the MEDLINE, Cochrane and Embase databases, without restriction to publication year. The keywords *ankle-brachial index (ABI), peripheral arterial disease (PAD), peripheral vascular disease, arterial occlusive disease, lower extremity* and *leg* were used for articles concerning the measurement of the ankle-brachial index. This search strategy yielded 568 articles on the ABI, 154 after title and abstract selection, and finally, 67 were deemed pertinent to respond to the research question. After analysis of the articles with Standards for the Reporting of Diagnostic Accuracy Studies (STARD), the reference's value for ABI for the presence of a severe PAD was determined to be smaller than 0.5 and over 1.3 (33).

A case study approach was used for this study.[42] The case study as a research method is appropriate for describing, explaining, predicting and controlling processes inherent in various phenomena, both individual and collective.[43,44] 'Explanation' aims to shed light on why things occur; 'prediction' seeks to establish, in the short and long term, what results will occur[42] and 'description' answers the questions who, what, when and how.[45]

In this study, the first ABI calculation method was performed according to Wounds Canada standards, by dividing the highest pressure between the two arteries in each foot (the dorsalis pedis and posterior tibial arteries) by the highest pressure between the two brachial arteries. The nurse performed all calculations at the time of measurement. The results were validated by a second evaluator before data compilation. The second method, ABI calculations and interpretations in the case studies, was with the choice of systolic pressure of one of the arteries of the foot, DP or PTA, which was made by considering which of the arteries best represented the location of the wound on the foot while respecting its angiosome. The research assistants used a programmed Excel chart to include many ABI methods calculations to compare at a subsequent time with the location of the wound on the corresponding photo (See Table 2).

Table 2: Example of an Excel chart illustrating different methods for calculating the ABI.

Arteries	Systolic blood pressure	Brachial Right arm	Brachial left arm	Mean right and left arms	Location of the wound
Monophasic or not	TB	135	132	133.5	
Right PTA	70	0.52	0.53	0.52	
Right DP	40	0.30	0.30	0.30	
Left PTA	128	0.95	0.97	0.96	
Left DP	85	0.63	0.64	0.64	

Photos used with permission of Maryse Beaumier.

Legend: posterior tibialis arteries (PTA), dorsal pedis (DP), Toe blood pressure (TB)

Table 3: Baseline characteristics of included patients

Variables	All patients n[%]
Women, n[%]	44[41]
Men, n[%]	64[59]
Characteristics	
Age, median	70.5[59-78]
Smokers or past smokers	67[62]
Diabetes, n[%]	59[55]
Chronic kidney disease, n[%]	19[18]
Amputated, n[%]	15[14]

Two case studies	Standard ABI calculation using value of PTA	Angiosome ABI calculation using value of DPA in respect of wound location and its angiosome
	0.83 Mild PAD	0.38 Severe PAD
	0.77 Mild PAD	0.50 Moderate to severe PAD

Figure 3: Two case studies

Photos used with permission of Maryse Beaumier.

Results

One hundred and eight (108) patients were recruited and documented on a case study form, totalling 295 lower limb wounds (captured in photos), representing 77 patients with a total of 143 wounds on the feet. Regarding the criteria measurements, 91.6% of patients have been assessed using the ABI measurement. In this study, using the angiosome concept, another ABI calculation was performed based on the systolic pressure of the specific artery supplying the wound location. All patients' and group-specific characteristics are summarized in Table 3.

The results from angiosome ABI calculation differed from the standard ABI calculation. In these case studies, 48% standard ABI calculations were representative of the artery irrigating the wound bed and 40% of them were not. Meanwhile, 12% had uncompressible arteries. Also, Doppler waveform sounds hold value in assisting ABI in the prediction of potential insufficient arterial blood supply. Toe blood pressure results were most useful in peripheral arteries with calcification, where ABI results are inconclusive.

Based on the angiosome concept, the specific angiosome ABI calculation was also found to have lower indexes than the standard ABI calculation, representing the closest reality of arterial vascularization to the wound, thus allowing for the best response to the first recommendation in order to properly assess it before making a clinical decision for wound care (See Figure 3). Therefore, taking the highest or lowest systolic pressure is no longer relevant to this approach, thus simplifying the harmonization of the method for clinicians.

Additionally, this approach emphasizes the significance of assessing systolic foot pressure between the dorsalis pedis (DP) and the posterior tibial artery (PTA) in order to conduct distinct calculations for each artery, thus enhancing a best PAD detection using the ABI.

Discussion

In patients with diabetes, peripheral artery disease (PAD) may go undiagnosed until they experience severe tissue loss.[46,47] It is crucial to address underlying PAD when caring for patients with lower extremity and foot ulcers.[6] Insufficient local vascular supply can lead to poor tissue oxygenation, promoting microbial growth, increasing the risk of infection and decreasing the likelihood of wound healing.[48] An incorrect assessment of the arterial vascularization of a foot wound can have serious consequences, leading to ineffective treatment, delayed or failed healing, amputations, a diminished quality of life and even premature death. An analysis of results from previous doctoral studies indicated that non-invasive instruments for assessing PAD do not always correlate well, and their effectiveness can vary based on the wound location and degree of arterial calcification.[32]

This variation can be explained by the concept of angiosomes, which suggests that each area of the foot has its own arterial blood supply and specific vascular territories.[39,40] Understanding the angiosomes of the foot and the interaction of their originating arteries is clinically beneficial, especially in the presence of PAD. This knowledge can aid in diagnosing PAD by allowing instruments to target arteries based on the location of foot wounds. The standard ankle-brachial index (ABI) calculation, which involves dividing the highest pressure measured between the two arteries in each foot (the dorsalis pedis and posterior tibial arteries) by the highest pressure recorded between the two brachial arteries,[49] may be inadequate when compared to a specific angiosome ABI calculation. This is particularly true when assessing arterial blood supply in cases of severe PAD and CLTI.

All the non-invasive instruments results help in the clinical decision for treatment of the wound. This clinical decision for selecting appropriate dressings differs significantly in cases of severe PAD and CLTI.[49,50] As stated in guidelines, "In arterial ulcers with sufficient arterial inflow to support healing, use a dressing that will maintain a moist wound-healing environment (Level IIA). Dry gangrene or eschar is best left dry until revascularization is successful (Level IIA)".[13]

Conclusion

Current clinical guidelines recommend conducting a comprehensive vascular assessment of the lower limbs, which includes measuring the ankle-brachial index (ABI) for patients with lower limb wounds.[11,12,14] However, the validity of this test can be suboptimal in cases of medial wall calcification in the main arteries, particularly among people with diabetes.[4,30,49,50] This limitation may lead to falsely elevated or normal ABI values in patients with diabetes, chronic kidney disease, or those who are older.[12,14] Individuals with diabetes often experience inconclusive and distorted results, which can result in an overestimation of actual vascular flow.[12,14,34,50,51] This population is particularly susceptible to PAD.[35-37]

This study aimed to examine differences in ABI calculations and interpretations based on wound location and the foot's angiosomes. By doing so, we hope to improve screening performance and enable a safe interpretation of results in patients with PAD or critical limb-threatening ischemia (CLTI). Previous case studies have demonstrated a significant difference between standard ABI calculations with and without considering angiosomes, showing a 40% improvement in PAD assessment when wound location is considered. To address the issue of false-negative results, clinical guidelines for managing PAD and CLTI recommend supplementing the ABI with either the absolute systolic toe pressure (TP) or the toe-brachial index (TBI) to enhance assessment accuracy. Both of these methods have been shown to be more sensitive in diagnosing PAD, and the calculation index is not necessary to avoid calculation errors.[51] Furthermore, as previously demonstrated, measuring toe pressure

using photoplethysmography (PPG) has a strong correlation (r=0.92, p < 0.001) with laser Doppler flowmetry (LDF).52 This makes manual toe pressure measurement an accessible first-line screening tool to complement ABI results.

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Starting A Limb Preservation Clinic: A Roundtable Discussion

Dr. Karim Manji

Abstract: Limb preservation clinics represent a paradigm shift in the management of complex diabetic foot disease and chronic limb-threatening ischemia (CLTI). Multidisciplinary limb preservation programs integrate vascular surgery, podiatric surgery, infectious diseases, endocrinology, nursing and other health professionals to provide coordinated, timely and evidence-based care. This collaborative model moves beyond reactive amputation-focused pathways toward proactive limb salvage strategies that address both 'toe' and 'flow'. This roundtable discussion brings together leaders in podiatric surgery and wound care disciplines to explore how integrated limb preservation models can be scaled, sustained and optimized.

Key words: *limb preservation, collaborative model, toe and flow, clinics, limb salvage pathways, podiatric surgery, wound care*

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Limb preservation clinics represent a paradigm shift in the management of complex diabetic foot disease and chronic limb-threatening ischemia (CLTI). As rates of diabetes and peripheral arterial disease continue to rise across Canada, the downstream consequences—ulceration, infection, hospitalization and major amputation—carry profound human and system-level costs. Multidisciplinary limb preservation programs integrate vascular surgery, podiatric surgery, infectious diseases, endocrinology, nursing and other health professionals to provide coordinated, timely and evidence-based care.

This collaborative model moves beyond reactive amputation-focused pathways toward proactive limb salvage strategies that address both 'toe' (local wound and infection management) and 'flow' (optimization of perfusion), recognizing that successful limb preservation requires simultaneous attention to both components. The importance of this approach is underscored by the work of many podiatric and vascular surgeons.

One Canadian team in Calgary established the Zivot Limb Preservation Centre in 2016, and has now established its second site in Edmonton to serve Northern Alberta in 2025. In their evaluation of a multidisciplinary limb preservation model in Alberta, they demonstrated a significant reduction in diabetes-related major amputation rates following program implementation. This landmark analysis, published in the *Journal of the American Podiatric Medical Association*, provided compelling provincial-level evidence that structured interdisciplinary care can alter the trajectory of limb loss.[1] Building on this foundation, a subsequent study further demonstrated that a regional multidisciplinary limb preservation program was associated with reductions in hospitalization rates, reinforcing the health system value of coordinated limb salvage pathways.[2]

Together, these findings affirm that 'Toe and Flow' clinics are high-impact clinical innovations that improve patient outcomes while reducing acute care burden. This roundtable discussion brings together leaders in podiatric surgery and wound care disciplines to explore how integrated limb preservation models can be scaled, sustained and optimized to prevent avoidable amputations and transform limb preservation care delivery.

Questions were posed to the roundtable panel by the author, Dr. Karim Manji, Director of Research at the Zivot Limb Preservation Centre in Alberta, Canada.

Expert Panel

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Q: Where is your limb presentation clinic located and when did it start? Who did you have to include in your Limb Preservation Clinic (LPC) - what was your irreducible minimum?

BH: Our limb preservation clinic is in the hospital. This provides us easy access to the inpatient units, as well as to the operating rooms, if we need to leave during clinic to do a case and then return. The clinic started in 2018 when I was recruited to the University of Alabama at Birmingham. Our program is under the division of vascular surgery and teaming with vascular surgery is essential to the development of a limb preservation program.

KP: Our limb preservation clinic was started in Edmonton, AB in 2025. The clinic was started with a collaboration between podiatric and vascular surgeons, as these specialties were considered the "irreducible minimum". We also have the ability to refer to internal medicine, infectious disease, diabetes educators, PT and OT, as well as other hospital based specialties.

FH: Our limb preservation clinic here is in Calgary, Alberta, at the Peter Lougheed Centre. We started the limb preservation clinic back in 2016. In conjunction with outpatient clinics, working side by side with other specialties, like infectious disease, vascular surgery, orthopedics and internal medicine, we were all working together in different pods as part of the outpatient clinics at the hospital.

Q: What were some of the biggest challenges to overcome when you started talking about building an LPC in your city?

BH: We have not really had any significant challenges with developing the program given the fact that it was determined that it was needed. It was developed with the support of our division, the Department of Surgery, the university and the hospital system. At this point our challenge now is appropriate clinical space. We currently have outgrown our space, and it is also located in a place which does not have easy access for patients who are trying to stay off their foot.

We are not near radiology, which can be an issue as well. We cover several hospitals within our health-care system, and I envision the day when we will become a single site program with patients at the other sites triaged and then sent to the hospital that our program would be housed in.

KP: Being based in Alberta, government funding and participation, as well as charitable donations, were needed to start the program. Because of this it took over 10 years before the clinic was finally established.

FH: Oh, there was a lot, anything from logistics involving record keeping, being involved in certain software for patient registration and getting prescription abilities in Alberta for the AADL

program for multidisciplinary clinics, so patients can have offloading shoes with insurance coverage. Also, having the ability to get orders sent and directed in the right location as well as referrals. All these minor details that we generally don't think about on a day-to-day basis were actually the most time consuming to sort out to get a functioning clinic.

Q: How many surgeons work on your team, and do you provide emergency call and patient services?

BH: Currently, our team consists of four podiatric surgeons and a nurse practitioner. Monday to Friday from 7am to 4pm our nurse practitioner does the inpatient rounding and sees any new consults and then staffs them with the on-call podiatric surgeon. In the evenings and on weekends the vascular surgery interns provide call coverage. We will see the inpatient consultation and then communicate with the on-call podiatric surgeon.

KP: Currently, there is one podiatric surgeon, with plans to expand, and approximately six to seven vascular surgeons involved in the limb preservation clinic. As the sole podiatric surgeon, I do provide in-patient services and make myself available for emergency calls. However, there is no formal call service. As the program expands, we plan to develop a formal call service to service the Edmonton area. The vascular surgeons take calls in the city.

FH: We're a group of seven podiatric surgeons that cover call coverage for emergency rooms and inpatients. Patients that come in can also be seen at the clinic.

Q: What do all LPCs need, regardless of location?

BH: All limb preservation clinics need close working relationships with vascular surgery. There needs to be vascular surgeons within the group that are dedicated to limb preservation. Patients with peripheral vascular disease who also have a diabetic foot complication may require multiple vascular interventions for healing to occur, so there is the need for vascular surgeons that are willing to do this and do not look at it as a 'one-and-done' deal. There also needs to be infectious disease clinicians presents to assist in the management of soft tissue and bone infection. This also requires a team of podiatric surgeons who are dedicated to limb preservation.

KP: In my opinion, all limb preservation clinics need a combination of podiatric and vascular surgeons. They need to have the ability to treat acute infections/emergencies as inpatients, along with treating chronic wounds on an outpatient basis. They need access to OR minor surgery facilities to provide the necessary interventions. Additionally, having easy access to a radiology centre where X-rays and vascular studies can be performed the same day, or in an expedited fashion, is beneficial.

FH: The number one thing is the ability to provide care for these patients; to be able to evaluate a wound, see if the wound is infected and be able to direct proper care. For example, the ability to have access to a vascular surgeon and/or infectious disease specialist, and if a patient needs to be treated with offloading, then the patient does need to be able to access that offloading device.

Q: What does your remission surveillance program look like?

BH: Currently, patients who are in remission will follow-up with our podiatric surgeons for surveillance. We are in the process of hiring a clinical podiatrist who will develop a remission and high-risk diabetic foot clinic. In my opinion, preventative care and education is overlooked and is probably the most important aspect of the limb preservation program. If we can prevent complications from occurring, then we are way ahead of the game.

KP: We currently use the IWGDF risk stratification system[3] to determine how often a patient in remission needs to be evaluated. If the patient falls in the high risk ulcer category they are encouraged to follow up with the limb preservation centre. Lower risk patients

have the option of following up in the clinic, with a community podiatrist or a diabetic high risk foot clinic.

FH: I think that's a very hot topic right now. Unfortunately, I think a lot of the clinics, due to funding and cost, are unable to have available staff to monitor patients. There is a limitation of being able to treat or to have a surveillance program in place. And in my opinion, that's a big reason why some of the patients re-ulcerate - it is due to the gap that we have in the remission surveillance program.

Q: Is it important to have a local champion? Who is yours?

BH: Because this problem is so prevalent in the Southeastern United States, we have many champions for our program. All the podiatric surgeons in our group are very passionate about diabetic limb preservation and are very strong advocates for the program. Our Chief of the Division of Vascular Surgery, as well as all the faculty members in our vascular group, is very supportive and vocal about the importance of our program. Our infectious disease colleagues and plastic surgeons are also extremely supportive of what we do and have been involved in the development of our program.

KP: It is important to have an advocate in the greater health-care system to build trust with other physicians, as well as to educate on appropriate referrals, as early identification is key. The local champion also helps to advocate for continued use of resources and resolves disagreements between team members and differing services. As our program is new in a city that did not previously have podiatric surgeons, the head of vascular surgery is our local champion.

FH: That's a good question, I think, unfortunately, some clinics have put one person in charge of the whole program, but it does leave that program vulnerable. I think it's best within a program if everybody is given the ability to become their own champion, and to be able to actually be a champion for their patients.

Q: Educating the next generation seems to be a vital component, what is your centre doing in terms of education?

BH: This year, we started a Diabetic Limb Preservation and Reconstructive Surgery fellowship. We have our first fellow this year, and it has been a very rewarding experience so far. In the next couple of years, we are looking at turning the fellowship into a two-year program, where a large amount of time can be committed to research.

KP: Currently, we participate in a weekly journal club with the Rose Zivot Fellowship program based in Calgary. As our program grows, we hope to get more involved with hands-on training of students, residents and fellows.

FH: Our centre is actually involved in educating the next generation of podiatrists, by having students in our clinic. We also have a fellowship training program. Here we have international doctors that come and spend some time rotating through our clinics. We also have infectious disease residents and vascular surgery residents that spend some time with us.

Family medicine residents are also being educated on the topic of diabetic foot care on a yearly basis. As the topic of diabetic foot ulcers is becoming something that everybody in the medicine is more aware of, I think that more people are developing an interest in how to better treat these patients. But most importantly, seeing the urgency in treating these patients.

Q: What are some effective strategies to educate local stakeholders on the work of your LPC?

BH: We have not really done any external marketing for the program. I think that the outcomes that we have achieved have resulted in patient referrals. Home health-care nurses who see your patients in follow-up in the community have also been very strong advocates for our program as they have seen the work that we have do.

There is such a high volume of patients that need care in the area that we really have not had to market the limb preservation practices.

However, once our program has stabilized, we will start more outreach programs and, with this, more marketing of our clinic.

KP: I have found small presentations to various departments helped to educate, referring providers on the new service being offered.

FH: Fortunately for us in Alberta here, a wonderful group called a Strategic Clinical Network stared a few years ago with a passion for diabetic foot. They put forward guidelines and pathways on how to treat and refer patients that have diabetic wounds, how often they should get a diabetic foot exam and which health-care professional should be involved in doing a diabetic exam, and these were actually distributed through the community through family doctors and primary care networks. I think the Strategic Clinical Network did a fantastic job developing these pathways and educating the public about how to properly use them.

Q: Timely access to care is critical with managing patients at an LPC, what does your site provide for timely access to urgent surgical care?

BH: Access to the operating rooms for urgent or emergent patients has not been a problem. Having relocated from Canada where emergency cases start after the regular OR day has concluded, I am now able to add two or three cases on and still be done by 5 or 6:00pm.

When on-call there is also a lot of access on Saturday and Sunday. If our members are on-call, they can manage patients that require further debridement or even a definitive procedure to get them moving closer to discharge.

KP: We are set up to perform the majority of foot and ankle cases under local anesthetic in our clinic. This allows us to perform more surgeries in a day than what could be done under sedation. This also allows us to provide same day surgery if an urgent case presents to the clinic or an inpatient emergency consult is placed.

FH: Yeah, you all know the good old saying, 'time is tissue'. That still stands today. When a patient has an infection, the faster you get to it, the faster you drain out the infection or remove the infected bone, the faster you can get rid of the infection and get the patient back to their activities, the less tissue they end up losing. Fortunately, we have something called minor surgery clinic where patients can have small procedures done under local anesthesia. So, we don't have to keep these patient NPO and wait or list them for surgery. They don't need to go under general anesthesia, or deeper anesthesia for minor procedure.

Like incision drainage, debridement or even partial foot amputation, those can be done under local anesthesia. And here we're able to do them quite rapidly because that minor surgery clinic is readily available for these high-risk patients.

Q: Lastly, what is one new team member you hope to bring in to your LPC in the near future?

BH: We recently added two new faculty members with expertise in Charcot reconstruction utilizing the newest internal fixation modalities, as well as intramedullary nails for pantalar fusions and external fixation.

We continue to recruit podiatric surgeons as our program expands into new hospitals that our system has acquired. At some point I would like to add a team member who has a strong interest in research and have time allocated for them for this.

KP: Being a new service with only one podiatric surgeon, we hope to expand the number of podiatric surgeons to increase the number of patients that can be seen, as well as to continue providing care in a timely manner.

FH: Well, you know, there's always that hope that somebody is going to come up with the magic treatment for healing all types of wounds. But unfortunately, this has not happened. I've been practicing for a few decades now and if I look back at my career, I can see that the treatment of diabetic foot has changed significantly over the past few years, and I think it's been a combination of endovascular surgery, new antibiotics and different treatment for the patient's diabetes.

Unfortunately, I still think that the number of diabetic wounds and amputations are still way too high. It would be nice to have a new team member who can help us by being more involved in the surveillance and prevention of wounds that have healed and in preventing recurrence.

Dr. Karim Manji is Director of Research at the Zivot Limb Preservation Centre, Calgary AB Canada.

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The Role Of Peer Support In The Amputation Journey

Paulo Polese, **Kevin Gray** and **Chris Ramhacklam**

Abstract: For limb preservation clinicians, amputation is often the final step in a long and complex clinical pathway. For patients, however, amputation is the beginning of a lifelong transition. While clinical teams focus on wound closure, surgical success and prosthetic readiness, research consistently shows that peer support and community connection significantly improve emotional well-being, confidence and functional recovery. This article discusses Limbloss Connection, a Canada-based peer support group founded by three amputees.

Key words: *limb loss, amputation, patient support groups, peer support, health professional-patient collaborations*

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For limb preservation clinicians, amputation is often the final step in a long and complex clinical pathway. Decisions are guided by perfusion status, infection control, tissue viability and the goal of preserving life. For patients, however, amputation is not the end of a clinical process. It is the beginning of a lifelong transition—one that is physical, emotional and social.

Across Canada, more than 300,000 people are living with limb loss, and thousands of new amputations occur each year, most related to diabetes and vascular disease.[1] More than 80 percent of lower-limb amputations are linked to these conditions.[2] While clinical teams focus on wound closure, surgical success and prosthetic readiness, research consistently shows that peer support and community connection significantly improve emotional well-being, confidence and functional recovery.[3]

This understanding is what led to the creation of Limbloss Connection.

Paulo Polese

Kevin Gray

Chris Ramhacklam

Genesis

Limbloss Connection was founded in June 2024 in Ontario, Canada by three amputees whose individual journeys were very different, but whose experiences after surgery were strikingly similar.

Paolo Polese's (Paolo) amputation came without warning. A rapidly spreading infection—necrotizing fasciitis—destroyed tissue in

his lower leg within hours. The medical team acted quickly, and the message was clear: a below-knee amputation was necessary to save his life.

"It all happened so fast," Paolo recalls. "One day I was fine. The next day I was being told I might lose my leg. I didn't have time to process it."

Kevin Gray's (Kevin) journey unfolded over years. Long-standing diabetes gradually reduced circulation in both legs. Despite careful wound care and multiple interventions, the damage progressed.

"It wasn't one moment," Kevin says. "It was a slow realization. Every appointment, the news got a little worse until there were no more options."

Kevin eventually underwent bilateral below-knee amputations. For both men, the clinical care was focused, professional and lifesaving. Emotionally, however, they describe the same experience: uncertainty, fear and isolation.

Chris Ramhacklam's (Chris) journey unfolded without warning. He didn't know exactly what had happened at first — only that something was suddenly, catastrophically wrong. What he would later learn was that sepsis had overtaken his body, escalating rapidly and silently.

"There wasn't a clear moment," Chris says. "I just remember things getting serious very quickly. I didn't fully understand what was happening — only that my life was in danger."

The progression was swift. To save his life, doctors made the difficult decision to proceed with a below-knee amputation. Clinically, the care was decisive, coordinated and lifesaving.

Emotionally, however, Chris describes a very different experience: confusion in the early days, fear as he tried to grasp the reality of his condition and a profound sense of isolation as he began adjusting to a future he had never imagined.

None of the three men knew another amputee or had a clear sense of what life would look like after surgery.

What ultimately helped these men regain confidence was not just rehabilitation or prosthetic training. It was meeting other amputees—people who had already walked the path they were beginning. From those experiences, the idea for Limbloss Connection emerged: an organization built around the simple principle that no one should face limb loss alone.

Structure And Current Function

Limbloss Connections is a non-profit peer support organization serving individuals with limb loss across North America. Its primary mission is to connect amputees with trained peers at every stage of the amputation journey, from the moment amputation becomes a possibility through long-term life in the community.

The organization provides peer visits before surgery, support during hospitalization, connections throughout rehabilitation and ongoing mentorship after patients return home. In addition to one-on-one connections, Limbloss Connections hosts virtual and in-person gatherings designed to reduce isolation and foster long-term community.

Funding comes through a combination of individual donations, corporate sponsorships, community fundraising efforts and partnerships with prosthetic and rehabilitation providers. Sponsors often support educational events, host meetings, provide training resources and help extend outreach into underserved communities. These partnerships allow the organization to grow while maintaining a patient-centered focus.

Reaching Individuals With Limb Loss

One of the central challenges in peer support is timing. Many amputees are unaware of available resources until well after surgery, when isolation and uncertainty are already significant.

Limbloss Connections reaches individuals primarily through referrals from clinicians, surgeons, rehabilitation teams and prosthetic providers. The organization also conducts community outreach and maintains an online presence so that patients and families can find support independently.

The goal is to connect with patients as early as possible—ideally before amputation—when emotional preparation and practical guidance can have the greatest impact.

What Peer Support Offers

Clinical care restores physical health and mobility. Peer support addresses the emotional and social dimensions of recovery.

Patients consistently report that speaking with another amputee provides something uniquely powerful: visible proof that life continues after limb loss. Peer mentors offer practical, experience-based advice on everything from navigating the home environment to managing prosthetic discomfort. More importantly, they provide reassurance, perspective and hope.

Clinicians support the organization primarily by introducing the concept of peer support and referring patients who may benefit from connection. Patients also have the benefit of peer-support networks and the value of supportive community groups in assisting the transition to their pre-amputation family, work and social roles.[4] Studies show that amputees who engage in peer support report improved optimism, greater independence and higher levels of social participation.[3] In some surveys, approximately three-quarters of participants report a more positive outlook after engaging in peer support programs.[5]

As Kevin explains, "What helped me most was talking to another amputee. We built Limbloss Connections so everyone could have that person."

Paolo adds, "Medicine saved my life. But community helped me live it again."

Working With Limb Loss Professionals

Limbloss Connections views clinicians as essential partners. Health-care professionals are often the first people to discuss amputation with a patient, and their recommendations carry significant weight.

Clinicians support the organization primarily by introducing the concept of peer support and referring patients who may benefit from connection. Even a brief introduction to an apportiately trained or educated peer can reduce anxiety and improve engagement in rehabilitation.[4]

From a clinical perspective, amputation is a surgical event. For patients, it is a life transition that affects identity, independence and social participation.

Peer support helps bridge the gap between medical treatment and real-world living.

"In rehab, you have a whole team around you," Kevin says. "At home, it's just you and your thoughts. That's when peer support matters most."

Future Plans And Expansion

Although Limbloss Connections is a young organization, its goals are ambitious. Over the next several years, the organization plans to expand its peer network into additional regions, strengthen hospital and rehabilitation partnerships and develop more structured peer training programs.

A central long-term goal is to make peer support a standard component of amputation care. The organization hopes to work closely with limb preservation specialists, surgeons, prosthetists and rehabilitation teams to build a more integrated model of care—one that addresses both the medical and human dimensions of limb loss.

Clinical Implications

For limb preservation and wound care teams, the evidence is clear: peer support is associated with improved psychosocial outcomes, greater independence, increased community participation and better overall quality of life.[3]

Introducing peer support early—ideally before amputation—helps patients prepare emotionally and practically for the journey ahead. For clinicians, this may be as simple as referring patients to a peer organization or encouraging them to connect with others who share their experience.

While surgery restores health and prosthetics restore mobility, community restores identity, confidence and purpose.

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The Association Between Clinical Obesity And Diabetes-related Foot Ulceration

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Abstract: Diabetes-related foot ulceration (DFU) remains one of the most multifactorial complications of diabetes mellitus, responsible for high rates of lower limb amputation (LLA), excess mortality and major health-system expenditure. Despite obesity and DFU growing exponentially worldwide and sharing many interconnected risk factors, peer-reviewed literature exploring the associations between these two conditions is limited. This review synthesizes epidemiological, genetic and mechanistic data to argue that obesity should be positioned centrally in DFU risk assessment and management. Establishing responsive and personalized treatments and management plans for individuals with obesity and DFUs is important for effective limb preservation

Key words: *diabetes mellitus, diabetes-related foot ulceration, risk factors, clinical obesity, lower limb amputation*

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Awareness of diabetes mellitus (DM) as a condition and comorbidity has grown significantly with technological breakthroughs and growing investment in research by governments across the world.[1] Despite obesity and diabetes-related foot ulceration (DFU) growing exponentially worldwide and sharing many interconnected risk factors, peer-reviewed literature exploring the associations between these two conditions is limited.[2] Further, DFU remains one of the most multifactorial complications of DM, responsible for high rates of lower limb amputation (LLA), excess mortality and major health-system expenditure. Despite advances in diabetes care, the global burden of DFU continues to rise.[3]

Obesity, with a prevalence nearing one billion people globally, is defined by the World Health Organization as "abnormal or excessive fat accumulation that poses a risk to health".[4] A DFU is defined by the International Working Group on the Diabetic Foot (IWGDF) as a full thickness wound that penetrates the epidermis and at least part of the dermis, occurring on the foot of a person with DM.[5] Recent estimates suggest that $231 billion US of intergovernmental funding is targeted towards treatment of DFU worldwide.[6]

Various psychological, socio-economic and biobehavioural factors are commensurate with chronic complications associated with obesity and DFUs.[7] Limited infrastructure and clinical resources within health-care systems directly impact the effectiveness of treatments and reduce continuity of care for service users.[8] Moreover, with increasing demand for screenings and treatments from ageing global populations and stretched capacity across health services and independent providers, cases of obesity and DFUs are rising.[9] While hyperglycaemia, peripheral neuropathy (PN) and peripheral arterial disease (PAD) are well-recognised drivers, excess adiposity has emerged as an up-stream modifiable determinant of both DFU incidence and delayed healing.[10] This review synthesises epidemiological, genetics, and mechanistic data to argue that obesity should be positioned centrally in DFU risk-assessment and management. Establishing responsive and personalized treatments and management plans for individuals with obesity and DFUs is important for effective limb preservation.

Obesity As An Upstream Driver Of DFU

Epidemiological and genetic evidence points to excess adiposity as an independent risk factor for developing DFU. In a cross-sectional study of 400 Sudanese patients, overweight individuals were more than twice as likely to have a DFU than those with a normal body mass index (BMI) (56 % vs 46 %; p = 0.04).[11] Comparable associations have been reported in other low- and middle-income settings. A Somali multicentre survey identified an odds ratio of 4.63 (95% CI 2.08–10.30) for DFU among overweight or obese patients,[12,13] while a retrospective cohort in Ethiopia demonstrated a high adjusted odds ratio of 27.76 (95 % CI 13.96–55.23) for ulceration in obese participants.[14]

Evidence from high-income countries supports a more indirect role of obesity. In a large prospective cohort of US veterans with DM Boyko et al. identified peripheral neuropathy, peripheral arterial disease and foot deformity as the dominant predictors of incident DFU, while body weight contributed primarily through interactions with plantar pressure and biomechanical stress rather than an independent risk factor.[15,16] Similarly, Lavery et al., incorporated body weight into multivariable DFU risk models, demonstrating that excess weight amplified mechanical stress and callus formation in neuropathic feet, thereby increasing ulcer risk indirectly.[17]

Genetic And Biomechanistics

Mendelian-randomisation analyses of more than 85 phenotypes in the FinnGen and UK-Biobank cohorts identified BMI as a stronger casual inference for DFU, diabetic polyneuropathy and peripheral artery disease, independent of glycaemic traits.[18] Each standard deviation increases in genetically predicted BMI increased DFU risk by ≈24 % (OR 1.24; 95 % CI 1.09–1.42 per kg/m²), with a modestly stronger effect in men.[18] Parallel analyses using the U.S. NHANES (1999-2004) demonstrated that BMI and newer adiposity metrics, weight-adjusted waist index (WWI) (OR=1.95), body roundness index (BRI) (OR=1.47) and relative fat mass (RFM) (OR=1.13), were positively associated with prevalent DFU after multivariable adjustment (BMI OR 1.07 per unit).[19] This suggests that indices capturing central adiposity and lean-mass deficits may be more informative for DFU risk stratification.

These epidemiological findings align with mechanistic evidence linking obesity-driven chronic inflammation, endothelial dysfunction and insulin resistance to impaired microvascular perfusion and delayed wound healing.[20] Biomechanical studies further demonstrate that increased body weight raises plantar pressure, particularly beneath the forefoot, providing a mechanical substrate upon which neuropathy and vascular disease act to precipitate ulceration via repetitive micro-trauma in insensate feet.[9] In patients with diabetic neuropathy, higher body weight has been shown to increase plantar stress, while modest weight reduction reduces plantar loading, supporting a causal biomechanical pathway linking obesity to DFU risk.[21,22]

These mechanisms act across the patient-, limb- and ulcer-related risk domains described by Monteiro-Soares and colleagues, ultimately shaping DFU incidence, healing trajectory, amputation risk and mortality.[23] (See Figure 1.)

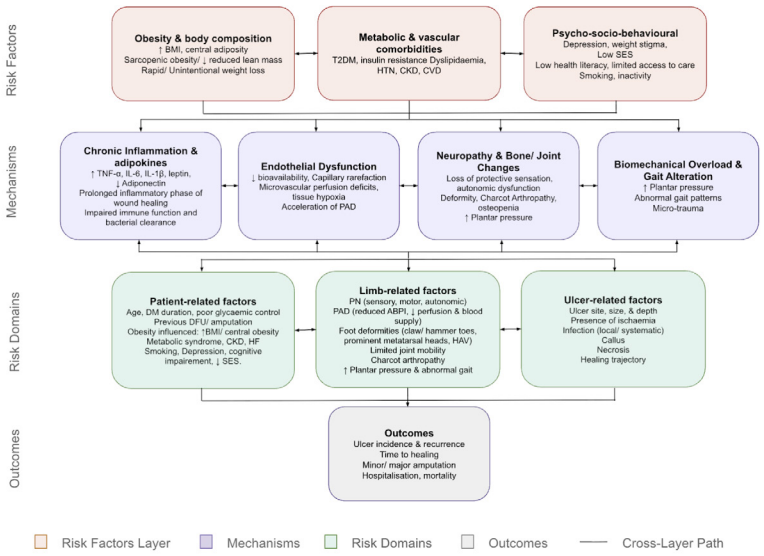

Figure 1: Multifactorial pathways linking obesity to diabetic foot ulcer risk and outcomes, structured by patient-, limb- and ulcer-related factors adopted from Monteiro-Soares et al., 2020.

DFU and obesity represent a multifactorial nexus, each exerts independent pathogenic effects (inflammation, insulin resistance, endothelial dysfunction, altered biomechanics) that synergistically worsen ulcer risk. Therefore, a coordinated, multidisciplinary approach targeting metabolic, vascular, biomechanical and psychosocial factors is required.

Obesity And Ulcer Severity Or Healing Outcomes

Among patients with established DFU, most prospective investigations report that a higher BMI was associated with delayed wound healing and increased amputation risk. In a Saudi Arabian cohort, individuals with normal BMI achieved complete ulcer healing within three months in 61% of cases, compared with 24% of obese patients. Participants with obesity also required longer treatment durations and experienced higher amputations rates.[24] A similar pattern was observed in a Pakistani cohort of 125 inpatients, where obesity correlated with larger ulcer size, prolonged duration and a 18.4 % amputation incidence.[25] An Indian prospective study of 102 patients with DFU concluded the obesity paradox was unsupported, as higher BMI and HbA1c were strongly associated with non-salvageable limbs.[26] These clinical findings may be explained by the biological impact of obesity on wound repair. The inflammatory, proliferative and remodelling phases of cutaneous repair are each vulnerable to the combined effects of systemic inflammation, hypoxia and mechanical stress. Consequently, obesity can prolong the inflammatory phase, blunt angiogenesis, impair fibroblast migration and reduce collagen maturation, hallmarks of the delayed healing observed clinically in obese DFU patients.

Weight Reduction, Bariatric Surgery And The Diabetic Foot

The clinical impact of intentional weight reduction on diabetic foot outcomes remains unclear. A case report described a woman with class III obesity (BMI 54.5 kg/m²) who achieved substantial weight loss following bariatric surgery and improved glycemic control, yet continued to experience neuropathy and foot deformity.

Increased physical activity combined with unmodified footwear preceded the development of a new ulcer and Charcot neuroarthropathy.[27] A recent scoping review identified only two relevant publications, both case-based, suggesting that rapid weight loss may alter foot biomechanics and increase susceptibility to Charcot changes.[28]

In more recent years, modern pharmacological weight loss therapies, such as GLP-1 receptor agonists, have proven to suppress the appetite.[29] A narrative review concluded that from the ten studies they reviewed, these medications can reduce caloric intake by 16-39%.[30] Meanwhile, patients with DFU typically require higher amounts of protein and energy in their diet to support healing (approx. 30-35 kcal/kg/day and 1.25-1.5 g/kg/day of protein).[31] As identified in a recent scoping review, the substantial reduction in caloric intake inadvertently limits the amount of protein and key micronutrients required for collagen synthesis and delays the progression through inflammatory and proliferative phases of wound healing.[32]

While these therapies offer clear benefits in improving glycemic control, their use in patients at risk of diabetic foot complications should be accompanied by a MDT to monitor potential nutritional and biomechanical risks.

In contrast, a randomized nutrition intervention trial in overweight and obese DFU patients (mean baseline BMI = 33.5 kg/m²) demonstrated that tailored dietary education and supplementation accelerated ulcer healing by approximately thirteenfold without worsening glycaemic control, indicating that nutritional optimization rather than weight loss alone may drive improved outcomes.[33]

Earlier studies similarly reported that poor nutritional status predicts delayed healing and adverse outcomes independently of BMI, reinforcing that nutritional adequacy is not reliably captured by body weight alone.[34]

The 'Obesity Paradox' In DFU

The concept of an 'obesity paradox' originates largely from cardiovascular and DM mortality studies, where overweight status has been associated with lower mortality, a pattern widely attributed to residual confounding, reverse causation and survival bias.[35] In the UK CPRD and Scottish Diabetes Research Network cohort, overweight and obese individuals demonstrated lower DFU incidence after extensive adjustment. The authors described these findings as novel and noted the potential influence of residual confounding and survival bias.[36] In contrast, systematic reviews of diabetic foot cohorts consistently associate underweight status with higher amputation and mortality, while higher BMI is linked to increased ulcer incidence and delayed healing.[37] However, these associations diminish after accounting for reverse-causation (weight loss due to chronic illness), survivour bias and incomplete adjustment for comorbidities. In contrast, among patients with established DFU, higher BMI consistently predicts larger ulcers, slower healing and more amputations, arguing that the paradox is a statistical artifact rather than a true protective effect. However, there is a gap in the literature addressing this, which requires studies with larger sample sizes to form generalizable data. Overall, current evidence therefore favours viewing obesity as a modifiable risk factor rather than a protective factor in the context of DFU.

Table 1: Links between Obesity & DFUs

Links between Obesity and DFUs	
Body Mass Index	Biomechanical loading, genetics, increased risk of neuropathy and PAD.
Chronic Inflammation	Endothelial dysfunction, impaired microvasculature, delayed wound healing.
Poor nutritional status	Appetite suppression, rapid weight reduction, inadequate protein and micronutrient consumption.

Psycho-Socioeconomic Biobehavioural Factors

Intertwined with the pathological process of obesity are further intrinsic and extrinsic factors which contribute to a compromised wound healing environment and poor adherence to DFU management plans. The Psycho-Socioeconomic Biobehavioural (PSB) Framework categorizes these areas into key constituent parts.[38] (See Figure 2.)

Firstly, psychological barriers to adherence in patients with obesity and DFUs may include mental health conditions such as depression and anxiety or ambivalence to self-care plans.[39] Existing systematic reviews have included studies which suggest that patients aged between 33-79 are more likely to display symptoms of major depression following admission in an acute hospital setting.[40] This places a unique spotlight on acute multi-disciplinary foot care and the importance of addressing a patient's psychological state alongside the treatment of a DFU. Moreover, patients referred to community podiatry clinics following discharge from the hospital may experience a continuation of these symptoms. This emphasizes the need for patient notes to highlight depression as a key indicator of adherence in a patient's health-care records.

Second, socioeconomic barriers to adherence in patients with obesity and DFUs may include unemployment, lack of mobility and urbanization. The 2024 Darzi Report investigating the NHS in England highlighted that "health inequalities are headed in the wrong direction" with the poor housing, low income and insecure employment contributing to increased demand from a "society in distress", including a rapid increase in rates of obesity. This is an important backdrop to the challenges clinicians face in addressing complex socioeconomic barriers alongside foot health inequity.[41]

Third, biobehavioural barriers to adherence in patients with obesity and DFUs may include iatrogenic weight loss from GLP-1 receptor agonists, Vitamin D deficiency, sleep apnea and self-neglect.[42] A recent multicentre cross-sectional study suggests this is particularly prevalent in developing countries such as Ethiopia.[43]

However, further primary studies are required to better understand the association between these conditions and specific behaviours in individuals with obesity and DFUs to advance health, disease risk and recovery globally.

By incorporating motivational interviewing techniques (engaging, focusing, evoking and planning) into the provision of education, ascertaining barriers earlier in a patient's care can be addressed.[44] With the SINBAD classification system for DFUs validated internationally as a communicative tool between clinicians,[45] a validated system is required for communication between a clinician and patient to address barriers to adherence. Primary studies investigating the validity and reliability of the PSB framework are required to provide clarity on its efficacy in clinical practice.

Conclusively, the complexity of the solution to poor adherence in patients with obesity and DFUs is commensurate with the conglomerate of barriers which a patient may reveal.[36] By integrating elements of motivational interviewing techniques into patient communication, clinicians are better placed to elicit vital information pertaining to barriers to adherence in patients with obesity and DFUs.

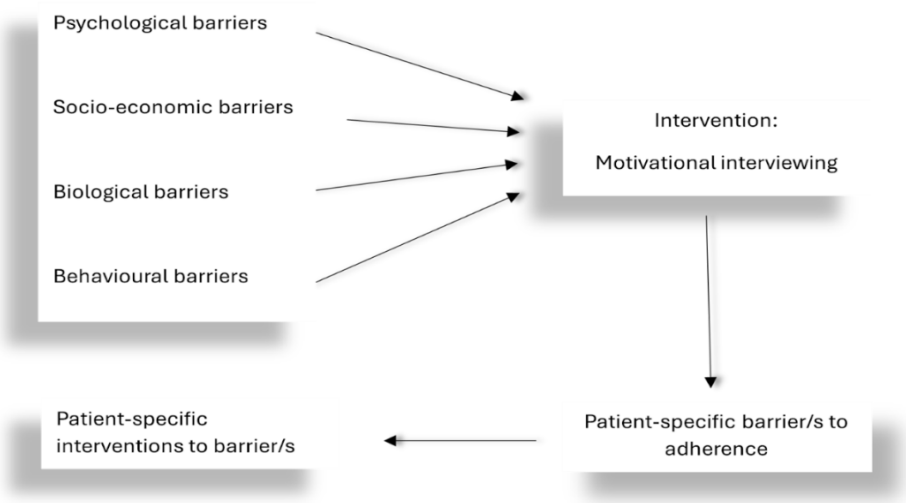

Figure 2: Psycho-socioeconomic Biobehavioural Framework for addressing barriers to adherence in patients with obesity & DFUs

Conclusion

The rise in global cases of obesity and DFUs suggests urgent action is needed across health-care sectors to manage commensurate increases in demand for wound care.

Current literature reveals several key gaps in evidence. First, longitudinal studies tracking changes in BMI, central adiposity indices such as WWI, BRI and ABSI and sarcopenic obesity in relation to incident DFU are needed to define dose response relationships and sex specific effects. Second, prospective trials examining the effects of intentional weight loss, through surgical or lifestyle interventions, on plantar pressure, bone density, neuropathy progression and ulcer recurrence are required to inform clinical guidance. Third, integrated intervention studies combining weight management, nutritional optimization, glycemic control and structured foot protection strategies, including custom orthoses and multidisciplinary foot care, should evaluate whether a comprehensive approach improves long-term outcomes. Until such evidence is available, excess adiposity should be considered a modifiable upstream determinant of DFU, alongside established vascular, neurological, metabolic and biomechanical contributors to ulcer development and healing.

With an increase in ageing populations and non-communicable diseases worldwide, eliminating ritualistic practice with better communication channels between podiatrists and multi-disciplinary teams can improve visibility of outcomes and coordination of bariatric care and DFU care. By developing clear clinical pathways between podiatry and nutrition services, wound balance can be achieved, alongside better performance frameworks and surveillance initiatives to advance limb preservation outcomes.

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CASE REPORT

A Two-island Limb Preservation Journey

Simone McConnie BSc Pod Med MRCPod MBA HCPC (UK) FFPM RCPS(glasg) and **Emerson Budhoo** MBBS MRCS ED (UK) DM (Ortho) CWS FRCS (UK) Foot & Ankle Fellowship (UK)

Abstract: This case report follows a gentleman (starting at the age of 57), with a diabetic foot who underwent several treatments, including diabetes management, offloading, orthotics, ray amputation and foot and ankle surgery in a successful attempt to prevent limb amputation. The case involves podiatry, general surgery and foot and ankle surgery across two islands in the Caribbean (Barbados and Trinidad).

Key words: *neuropathic diabetes, diabetic foot, orthotics, ray amputation, limb presevation, foot and ankle surgery, multidisciplinary teams*

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Multidisciplinary teams are deemed the gateway for limb preservation, but only a few countries, with adequate resources, are able to achieve this team approach with the efficiency and balance that truly enhances the chances of success.

A podiatrist, wound care specialist, orthopedic/podiatric foot and ankle surgeon and, when needed, a vascular surgeon — all with special interest in limb preservation, along with the necessary acumen — are required to achieve the best results for the patients. In this case report, we explore the concept of treating a patient with the various members of this team spread across international borders in the Caribbean. With no formal complete local team, and limited access to adequate resources, how can we win? How do we preserve the limb? How do we heal the wound?

Patient Characteristics

FL is a 57-year-old male from Barbados who presented in June 2019 with a neuropathic diabetic ulcer. The patient had a good vascular supply and a BMI of 24.9 kg/m2

The patient is a professional and passionate tennis player and coach and was motivated throughout by the desire to return to his profession.

FL was initially treated by a local general surgery team. Examinations led to further consultations from a podiatrist with a diabetic foot and wound care specialty (the lead author).

Initial Treatment

The patient was hospitalized for his right diabetic foot. His initial care was managed by general surgery and the podiatrist with the aim of foot preservation.

FL was counselled on compliance to a hyperglycemia regimen and clinic follow ups. The general surgeon and podiatrist managed the wound via debridement and drainage, combined with soft tissue and bony samples.

Figure 1: June 2019

FL's footwear consisted of a forefoot offloader. These measures were aimed at achieving foot preservation, therefore the first ray fat pat was preserved instead of having the method of a 'guillotine effect,' taking away the fat pad, as well as the loading area. FL was asked to reduce activity due to his height and weight. An appropriate blood sugar management regime was also agreed to by the patient.

Figure 2: December 2019 - fully resolved. There was some delay in healing due to mild osteomyelitis that remained but was resolved with antibiotic beads.

On healing, FL was introduced to customized orthotics, but was "not interested" at the time, citing "all the education" required. His only interest was in "getting back on the courts."

The left foot had also had an amputation of the 5th ray, leaving the base. This resulted in a supination of the left foot with gait.

Ongoing Challenges

In Jan 2020, FL presented with a blister over the left foot styloid of the 5th. It was offloaded with in-shoe adaptations and orthotics. The lesion fully resolved by February 2020.

At the end of February 2020, the right foot 3rd toe developed a blister on the dorsal area. This resolved within weeks.

In June 2020, the patient was seen as an emergency visit, as he reported thinking that he had "stepped on something" on the court with his left foot. On examination, there was no sign of injury. He was cast for new orthotics to be made in Canada.

Until October 2020, the patient remained active, helping to assemble a bed and playing tennis. That month, he presented with a warm, right oedematous ankle. Suspicion of Charcot in the ankle was confirmed via Xray. He was put in a boot for two months. An ankle brace was recommended, which he felt was better than the boot. Patient education on the importance of offloading and use of the boot was provided. FL agreed to four more weeks of the boot and then used the ankle brace, as he felt unstable. High top footwear was suggested, but he refused this option, preferring the brace.

In January 2021, FL developed a nail fungus on the left foot 3rd toe. This was managed with topical treatment and resolved in two weeks. At the end of January, he presented as an emergency with another blister on the plantar lateral aspect of the left foot styloid 5th, which resolved in four weeks. However, around February, he received his new shoes and custom orthotics. He wore the shoes with no orthotics and refused orthopedic footwear, as he thought they made him "walk funny" and that the shoes "were ugly." The blister came and went as the patient would remove dressings at home and redress between clinics, as he needed to take frequent showers, and some of the devices used to keep it dry were not successful. He eventually resorted to black plastic garbage bags tied around his thigh.

The blister and fungus eventually resolved. The patient was not seen for a while, returning in June/July 2021 with a calloused/blistered area on the left foot under the 5th styloid. This was drained and started to resolve, but the patient started doing home dressings and presented at emergency one day febrile, and was admitted to hospital under the care of his previous general surgeon. The area was extensively debrided and drained. Culture results identified Gram positive *cocci* and Gram negative *bacilli*.

Figure 3: Post debridement

Figure 4: Fully healed by October 2021

The patient was reviewed and refitted with new orthotics, given the changes to his foot. He was provided with strict criteria on offloading and dressing routines,

FL was fitted in November 2021 with new shoes and customized orthotics. He was content and happy. He even ordered a second pair of footwear and remained healed. He was reviewed for managed care, receiving callous removal and footwear and orthotic reviews, along with consultations with his diabetologist on blood sugar regimes as needed.

In September 2022, FL presented with a fissure and Plantar callous with mild exudate on the right foot which resolved within a few weeks.

He remained stable until February 2023, when on the right foot PMP 1, the small lesion came back, indicating blistering and friction to the area. A review of orthotics and footwear was done. The area resolved and broke down over a six month period. Xrays revealed a change in the morphology of the foot with a more plantarflexed 1st digit stump, and by June 2023, he started to develop shearing callous lesions and fissures under the Met 3/4/5 areas. Xrays confirmed callousing of the bone, which would be as a result of new loading to the foot with walking.

Figure 5: Plantar callous

Figure 6: Persistent healing and reulceration during 2023.

Xray showed periarticular soft tissue calcifications, periosteal reaction and articular surface irregularity of the third right metatarsophalangeal joint redemonstrated (See Figure 7).

Figure 7: Xray

It was determined that all the lesions would likely resolve and repeat, and in December 2023, we discussed realignment of the foot with a foot and ankle surgeon in Trinidad, as that specialty is not available locally in Barbados. The surgeon (the co-author) was consulted and FL was duly referred.

The procedure proposed was a right 1st metatarsal exostectomy+/- dorsiflexion osteotomy 1st metatarsal base and a Weils osteotomy of lesser toes.

The procedure was performed in June 2024. The patient had clinical prep tests (ECG, blood tests) done in Barbados, along with pre-op consultation. FL then flew to Trinidad just for the procedure. He was in Trinidad for four days. The procedure was performed successfully, and the patient returned to Barbados for follow-up care, pin removal and wound management. He went on to fully heal by August 2024.

Figure 8: Right foot post procedure.

Figure 9: Healing.

Figure 10: Fully healed by August 2024

Figure 11: New lesion under plantarflexed stump.

Figure 12: Post op procedure- no plantarflexion noted.

In September 2025, a further change associated with his foot resulted in a PMP stump area persistent ulcer. The patient requested intervention to realign the digit after it was ascertained that it was now plantarflexed, causing the ulceration.

FL reported that he had had so much faith in the surgeon and procedure previously done in Trinidad, he had opted for the surgeon to review the foot and surgically offload the ulcer.

The angle in Figure 12 shows the completed procedure and shows that the area is no longer plantarflexed. There was a delay in healing because FL "felt great" and did too much on the foot, tearing the stitches. However, he still healed by November 2025, by secondary intention.

FL is currently awaiting a molded customized orthotic. He is walking and playing with his grandson. We know his journey may not be over but with the interventions he has had, we have preserved his quality of life, his psychological and mental health and allowed him to live as full a life as he deserves.

Figure 13: Healed foot November 2024

Conclusion

This perhaps complicated journey was, nevertheless, a reminder that limb preservation is not impossible if the right team works together, in whatever conditions and circumstances exist, and with available resources.

The ideal world of teams seeing a patient in the same room, at the same time, is not always possible, but with the emerging digital world, we are expanding our ability to integrate teams, not only between sites but across borders.

This is the reality of a diabetic foot. The first lesion is not necessarily the last lesion.

And although the patient could be resistant and not always advocate for himself, we can still 'win' when we exercise the ability to tear down walls, egos, titles and borders, and properly see the patient as someone who deserves a limb and deserves two feet, even if not necessarily ten toes.

This particular patient, if he had agreed to an amputation at the beginning of this journey, would have had, from his perspective, a 'diminished' life, as a tennis player and a new grandfather.

Can we save all limbs? No, but with diabetic foot stratification, identifying a neuropathic foot, with no ischemia, paying attention to infection control and incorporating multidisciplinary teams specializing in the diabetic foot/limb preservation, any limbs can be saved and lives renewed, even in resource-limited environments.

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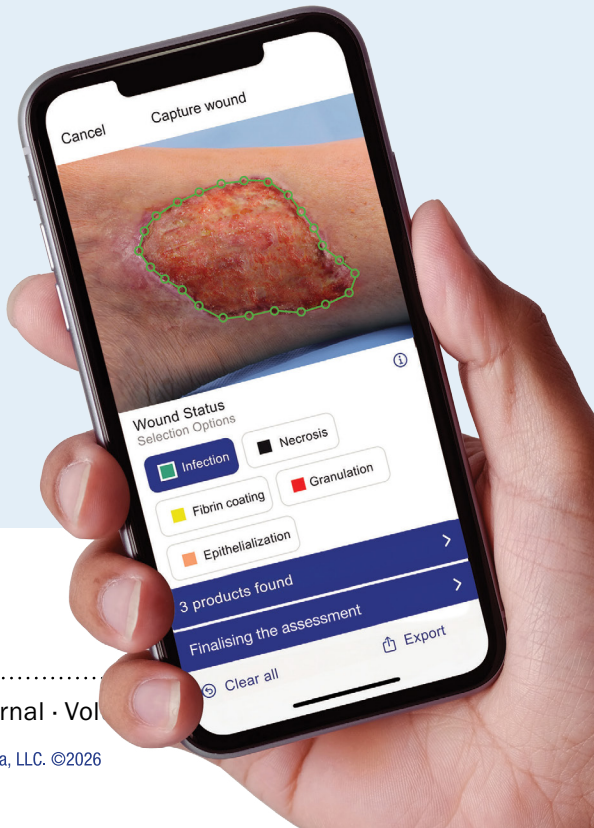

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D-Foot International: A Global Movement For Limb Preservation

Harikrishna KR Nair, Raidah R Gangji and **Zulfiqarali G Abbas**

Abstract: Every 30 seconds, a limb is lost to diabetes mellitus, yet the majority of the amputations are avoidable and surely preventable. D-Foot International is helping to change this reality across seven regions by creating a global movement that brings together health-care professionals, educators and policymakers. Through flagship programs such as *Train the Foot Healthcare Professional* and *D-Foot Awareness Day*, D-Foot International has taught and trained thousands, screened tens of thousands, and driven measurable reductions in amputation rates, morbidity and mortality. Its journey serves as a testament to what can be accomplished via coordinated actions: turning knowledge into life-saving practice. D-Foot International continues to evolve from a professional network into a global movement providing a platform for learning, leadership and limb preservation aimed at ending avoidable diabetes-related amputations.

Key words: *diabetic foot ulcer, lower-limb amputation, global health education, multidisciplinary foot care, train-the-trainer model*

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The fastest growing global health challenge of the 21st century is diabetes mellitus, with prevalence projected to increase substantially over the coming decades.[1] This rise is paralleled by an increasing burden of complications, with diabetes-related foot complications (DRFCs) having the highest morbidity and mortality rates. Approximately 19-34% of people living with diabetes mellitus (PLDM) may experience foot ulcers during their lifetime, and these remain the primary cause for lower-limb amputation.[2] The burden of DRFCs is disproportionately high in low-resource settings where health-care systems often are faced with limitations in infrastructure, trained health-care professionals (HCPs) and access to diagnostic and treatment services. Unfavourable and poor outcomes, including high rates of infection, amputation and death, are attributed to delays in presentation, inadequate screening and a lack of multidisciplinary care.[3-5]

In response to these challenges, global health efforts have increasingly focused on strengthening education, improving early detection and facilitating multidisciplinary collaboration. Within this context, D-Foot International is a global organization dedicated to addressing DRFCs through coordinated efforts in clinical practice, collaboration and education. This article reflects on the organization's journey, examining its evolution, key initiatives and contributions.

Mission And Vision: Building A Global Network

D-Foot International was established with a core mission, "to end avoidable lower limb amputations due to diabetes worldwide". From its inception, D-Foot International recognized that addressing DRFCs requires more than clinical expertise alone. It requires a coordinated approach that incorporates clinical care, education, prevention and policy engagement. The organization's structure reflects its global vision, with representation across seven regions: Africa, South and Central America (SACA), North America and the Caribbean (NAC), Middle East and North Africa (MENA), Europe, South-East Asia (SEA), and Western Pacific (WP). This multi-regional framework allows context-specific adaptation of strategies while maintaining a unified global mission.[6]

Early initiatives concentrated on creating a cooperative network of HCPs dedicated to improving diabetic foot care. D-Foot International positioned itself as a platform for professional development and knowledge exchange through collaborations, education initiatives and networking with global stakeholders. This foundation sets the groundwork for further growth, expansion and impact.

Flagship Programs

The flagship programs of D-Foot International encompass capacity-building initiatives, such as *Train the Foot Healthcare Professional (TtFHCP)* and *D-Foot Awareness Day*, which are uniquely designed to address gaps in diabetic foot care. These initiatives adopt a cascade approach, equipping multidisciplinary health-care teams with practical skills in prevention, early detection and management of diabetes-related foot complications, while enabling them to disseminate this knowledge within their local health-care systems.[6]

The TtFHCP programs have played a crucial role in this regard. These programs are designed to equip and empower clinicians with practical skills in diabetic foot assessment, prevention and management, while simultaneously encouraging them to train others within their own local settings. Built on a structured educational framework, the program combines didactic lectures, hands-on practical sessions and case-based learning to ensure both theoretical understanding and clinical application. In addition, the programme emphasizes a multidisciplinary and team-based approach, often requiring participants to attend as 'doctor–nurse pairs' to reflect real-world clinical practice and promote collaborative care. Interactive components, including simulated scenarios, case discussions and problem-solving exercises, further reinforce clinical decision-making and contextual adaptation of knowledge. The TtFHCP initiative evolved from an earlier Train the Foot Trainer (TtFT) program (2012–2020), which reached 14 countries in the SACA region, 20 countries in the NAC region, 18 European countries, 13 WP countries, 12 French-speaking African countries and 14 MENA region nations. Building on this foundation, the TtFHCP program (2023–2025) was conducted across six regions, encompassing 11 African countries, eight SACA countries, 12 WP countries, 10 European countries, five MENA countries and four SEA countries.[7-16]

The preliminary impact data from the recent 2023-2025 TtFHCP conducted in SACA region (Colombia), WP region (Malaysia), Europe region (Slovenia), Africa region (Tanzania) and MENA region (Pakistan) showed an approximate of 800 FHCPs trained. Published impact data by Abbas and Hari (2025), including 15 centres across four regions demonstrated the program's reach and impact. Following training, over 30,000 PLDM were seen across these centres, of whom 7,812 were screened for high-risk feet, identifying 4,640 PLDM with either peripheral neuropathy or peripheral arterial disease. A total of 11,875 diabetic foot ulcers outpatients were managed with 973 admissions and 70 major amputations (7.2% of admitted patients) and 27 deaths (2.8% of admitted patients). The educational cascade yielded 123–174 HCP education sessions per region, training 82–136 doctors and 27–600 nurses, alongside 75–236 patient education sessions delivered by trained HCPs.[7-16]

Importantly, after TtFHCP training, participants are encouraged to collect data, implement local foot care services and conduct training sessions upon returning to their respective institutions, thereby creating a cascade effect of knowledge transfer. This 'train-the-trainer' model guarantees sustainability and scalability, especially in settings with low resources. By integrating education with practical skill development and local implementation, the TtFHCP program serves not only as a training initiative, but also as a functional model for strengthening diabetic foot care systems and reducing preventable amputations. However, as acknowledged in the published paper, limitations include the lack of long-term retention data for clinical skills, heterogeneous data collection methods across centres and the absence of a control group for causality assessment.[5,7]

The *D-Foot Awareness Week* campaign, which recently converted into the *D-Foot Awareness Day* campaign, exemplifies this approach, serving as a coordinated global effort aimed at promoting visibility of DRFCs and elevating early intervention strategies. The D-Foot Awareness Day is sectioned across the seven defined regions, with one global session that unites international experts, clinicians, researchers, policymakers and stakeholders in a unified platform to address key themes in diabetic foot care. Between 2023-2025, this campaign hosted a total of 115 specialists from all seven regions, reflecting the diversity of the global diabetic foot community. For the 2025 D-Foot Awareness Day, a total of 43 specialists participated with representation from all seven regions. The series of regional sessions are tailored to the local health-care context, addressing region-specific challenges and solutions. This dual structure of combining a global session with regionally adapted sessions is unique, providing a platform for context-sensitive dissemination of knowledge catering to a variety of professionals involved in diabetic foot care. By integrating advocacy with education and clinical engagement, the D-Foot Awareness Week campaign represents a strategic effort to bridge the gap between knowledge and practice. It highlights the importance of sustained public health messaging and reinforces the global commitment to reducing avoidable lower-limb amputations due to diabetes.[17,18]

Education, Advocacy And Awareness

A defining feature of D-Foot International's approach has been its emphasis on education as the primary driver of change. Recognizing that many amputations are preventable through early detection and appropriate management, the organization has prioritized capacity building among HCPs. D-Foot International has created a comprehensive portfolio of educational events, including webinars and conference sessions. These platforms encourage the sharing of opportunities for continuous professional development (CPD) and facilitate the dissemination of emerging evidence and best practices.

The *Webinar Saturday* series, which has developed into a consistent and accessible global learning platform, covers a wide range of subjects in relation to DRFCs. The regularity of these webinars encourages CPD and successfully overcomes geographical barriers, enabling real-time interactions, case-based discussions and multidisciplinary engagement. Between 2023 and 2025, the Webinar Saturday series was strategically structured around key thematic areas aligned with major guideline frameworks, particularly those of the International Working Group on the Diabetic Foot (IWGDF). Topics were organized to reflect the core domains of diabetic foot care, including infection management, peripheral arterial disease, wound classification, offloading strategies and surgical interventions. This thematic approach ensured systematic coverage of essential clinical concepts while reinforcing evidence-based practice and guideline implementation across diverse health-care settings.[19]

Building on this foundation, the 2025–2027 webinar series has evolved into a more interactive and clinically immersive format, adopting a case-based 'Sherlock Holmes' approach to learning. In this model, real clinical cases are presented in a stepwise manner, encouraging participants to engage in diagnostic reasoning, interpret clinical findings and formulate management plans collaboratively. This approach emphasizes critical thinking, pattern recognition and problem-solving skills, reflecting the complexities of real-world diabetic foot care. By shifting from primarily didactic teaching to an inquiry-driven format, the series enhances learner engagement and facilitates deeper understanding of clinical decision-making processes.[20]

This evolution of the Webinar Saturday series from the IWGDF guideline-based thematic approach to interactive case-based learning shows a progressive education approach that integrates evidence, clinical reasoning and experience. It strengthens D-Foot International's position in providing adaptable, high-impact education platforms that address the changing demands of HCPs and, ultimately, contribute to improved patient outcomes.

In parallel, D-Foot International further solidifies its position as a global hub for diabetic foot care by actively participating in and organizing significant regional and international conferences. These include participation in global wound care congresses, diabetes-focused scientific meetings, and dedicated D-Foot International conferences held in collaboration with partner organizations. These conferences serve as high-level platforms for the exchange of scientific knowledge, presentation of emerging research and alignment of global practices in diabetic foot management. To date, D-Foot International has successfully convened three international conferences, each marking a progressive step in strengthening global collaboration and advancing multidisciplinary diabetic foot care. Building on the success of these conferences, D-Foot International is preparing to host its fourth international conference, which is expected to further strengthen global partnerships, showcase ongoing research and promote innovative strategies for the prevention and management of DRFCs.[8-16]

Collectively, these educational platforms reflect a strategic approach to capacity building that extends beyond traditional learning models. By combining virtual education, in-person training and international collaboration, D-Foot International has created a sustainable ecosystem for professional development. The emphasis on education reflects the fundamental principle that D-Foot International works upon: prevention begins with knowledge.

From Research To Implementation

In addition to its educational and advocacy initiatives, D-Foot International has increasingly positioned itself as a contributor to global research in diabetic foot care. Recognizing that sustainable reductions in diabetes-related amputations require robust and context-specific evidence, the organization has actively supported multicentre studies, implementation-focused research and global data collection initiatives across its seven regions.

A major milestone in this regard is the Global Cost Study on Diabetic Foot Ulcers, conducted across 36 countries and 51 centres, representing one of the most comprehensive multicentre datasets in diabetic foot care. The preliminary findings indicate that the mean cost per ulcer episode ranges from $1,200 for low-income countries to $18,000 for high-income countries (all figures in USD), with amputations doubling or tripling costs. This study provides critical insights into the economic impact of diabetic foot disease, highlighting the substantial health-care costs associated with delayed presentation, advanced disease and amputation. In addition to economic evaluations, D-Foot International also conducted research evaluating the implementation of the structured TtFHCP initiative. The findings provided important evidence on the feasibility and scalability of education-driven interventions in real-life settings.[21]

Partnerships And Policy

A further stage in the development of D-Foot International has been its increasing engagement with global health organizations and policy-oriented initiatives. Collaborations with international bodies, including major diabetes and wound care organizations such as the International Diabetes Federation, International Working Group on the Diabetic Foot, the Royal College of Podiatry and Foot in Diabetes UK and the Limb Preservation Alliance, have enhanced its ability to influence both clinical practice and health policy.[22]

These partnerships have enabled the co-development and dissemination of educational and clinical resources, including concise, practice-oriented info-cards designed to translate guideline recommendations into accessible tools for frontline health-care providers. By simplifying complex clinical guidance into actionable formats, these resources support standardized approaches to diabetic foot care across diverse health-care settings. In addition, collaborative efforts have facilitated joint educational activities, international knowledge exchange and alignment with global best practices. Such partnerships also provide strategic platforms for advocacy, promoting the

integration of diabetic foot care into national health agendas and strengthening the recognition of diabetes-related foot complications as a priority within public health systems.

Lessons From The Journey: Challenges and The Way Forward

No global health initiative is without limitations and D-Foot International has several ongoing challenges which should be acknowledged. In terms of cascade training's sustainability, the TtFHCP initiative still remains completely dependent on D-Foot International's efforts. These need to be decentralized to allow self-sustaining programmes to emerge and evolve that are tailored to local contextual settings and each specific institute or clinic. Long-term predictability and scalability are threatened by funding reliance on industry sponsorships and short-term grants. These limitations do not invalidate D-Foot International's achievements, but rather highlight areas for honest, strategic improvements. Additionally, we have a persistent data gap which remains a significant concern, as amputation rates, healing times and quality-of-life measures are not systematically collected across all seven regions. Furthermore, D-Foot International's governance structure does not include a formal patient advisory commute, which means that the voice of PLDM is absent from strategic decision making. And lastly, regional activity is unevenly distributed, with Africa, WP and SEA region showing high engagement compared to other regions.

Based on these internal reviews and external consultations, D-Foot International is making strides on identifying strategic priorities for the coming years to tackle the foreseen challenging circumstances. Collectively, these strategic priorities will aim to develop a 'roadmap' for transitioning from a well-intentioned network to a measurable, accountable and sustained global force in the battle against DRFCs.

Conclusion

D-Foot International has significantly grown from a small network into a global movement across seven regions. Its educational programs, research contributions and advocacy efforts have substantially advanced diabetic foot care worldwide. However, to truly end avoidable lower-limb amputations due to diabetes, D-Foot International, together with other similar organizations, must move from describing activities to demonstrating impact through sustained and accountable action.

For more information on initiatives and membership, visit: https://d-foot.org/

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