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Whitepaper Series

A Comprehensive Overview for Assessment Diabetic Foot Ulcers

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Introduction

A diabetic foot ulcer (DFU) can be defined as a full-thickness wound (i.e, involving the subcutaneous tissue) below the ankle, or as a lesion of the foot penetrating through the dermis, in people with type 1 or type 2 diabetes (Schaper 2004; Santema et al. 2016).

Diabetic foot ulcers (DFUs) represent one of the most serious and costly complications of diabetes, affecting millions of patients worldwide (Armstrong et al., 2017; Lazzarini et al., 2018). They are not simply wounds on the foot; they are the culmination of a complex interplay of neuropathy, ischemia, infection, and systemic metabolic dysfunction (Jeffcoate et al., 2018). DFUs profoundly impact patient quality of life, healthcare systems, and society at large, while prevention, early detection, and multidisciplinary management remain essential strategies (IWGDF, 2023). DFU's are the end stage of a disease process in the lower extremity(LE). There are visual screening assessment tools and recommendations by large organizations like the ADA and the IWGDF but none have received widespread adoption or acceptance. As a consequence, most patient's first entry points into the healthcare system are with lower extremity complications like ischemia or wounds. This is unlike other areas of diabetes care which include eye screening for diabetic retinopathy or blood glucose monitoring with glucometers or blood work such as HbA1c. There is a need in this sector for validated, objective tools to screen and standardize care, document risk and support earlier interventions.

Guideline Title	Organization(s)	Focus Area	Year	Lead Author(s)
WHS Guidelines Update: Diabetic Foot Ulcer Treatment	Wound Healing Society (WHS)	Treatment of diabetic foot ulcers	2024	Lavery et al.
IWGDF/IDSA Guidelines on Diagnosis and Treatment of Diabetes-related Foot Infections	IWGDF, IDSA	Diagnosis & treatment of foot infections	2023	Senneville et al.
Intersocietal Guidelines on Peripheral Artery Disease in People with Diabetes and a Foot Ulcer	IWGDF, ESVS, SVS	Peripheral artery disease management	2023	Fitridge et al.
Guidelines on the Prevention of Foot Ulcers in Persons with Diabetes (IWGDF 2023 Update)	IWGDF	Prevention of foot ulcers	2023	Bus et al. (published 2024)
Guidelines on Interventions to Enhance Healing of Foot Ulcers in People with Diabetes (IWGDF 2023 Update)	IWGDF	Healing interventions for foot ulcers	2024	Chen et al.
Guideline for Management of Patients With Lower-Extremity Wounds Due to Diabetes Mellitus and/or Neuropathic Disease: Executive Summary	Multidisciplinary (Bonham et al.)	Management of lower-extremity wounds	2022	Bonham et al.

Table 1 - Key Evidence Based Guidelines

Diabetic Foot Screening

Diabetic foot screening is a foundational component of diabetes management in the United States. Its primary goals are to identify patients at risk for ulceration, prevent avoidable complications, and reduce amputations through early intervention. National guidelines emphasize annual assessment for all patients with diabetes, with more frequent evaluations for high-risk individuals.

Why Diabetic Foot Screening Matters

High prevalence: Over 37 million Americans have diabetes, with an estimated 34% developing a foot ulcer at some point in their lifetime (Armstrong et al, 2023).

High cost: Diabetic foot complications are one of the most expensive diabetes-related conditions.

Preventability: Up to 85% of amputations can be prevented with routine screening, risk stratification and early treatment.

Remission & Recurrence: It is critical to reframe 'healed' diabetic foot ulcers not as cured, but as being in remission. New data published in the International Wound Journal (Armstrong et al, 2025) indicates that the 3-year recurrence rate for diabetic foot ulcers is 58%, while the reintervention rate for chronic limb-threatening ischemia (CLTI) is 50%. These rates are comparable to, and in some cases exceed, the recurrence rates of advanced breast, prostate, and lung cancers. This 'cancer-like' recidivism underscores the urgent need for objective, continuous surveillance—using tools like thermography and tissue oximetry—to detect early warning signs during the remission period.

US DFU Screening Guidelines

Several professional bodies have recommended frameworks that are used across clinical settings. The American Diabetes Association (ADA) recommends an annual foot exam for all patients with diabetes. High risk patients - those with neuropathy, prior ulcers, deformity or PAD- should receive exams at every visit. This is supported by the American Podiatric Medical Association (APMA) and the IWGDF.

There are four core components to the diabetic foot exam which include a history, skin exam, a neurological, vascular and a musculoskeletal exam of the foot for deformities.

There are common screening tools used in the US which include the ADA comprehensive foot exam (see table 2).

However, there is no universal standard for diabetic foot screening, the tests are highly subjective and not standardized. The purpose of a screening tool is to understand the next steps in foot care as a proactive approach to preventing DFU's. In Primary care, only 29% of primary care doctors perform all four components of the diabetic foot exam and there is very little written about the accuracy of the assessment. There is very little data on the true accuracy of the tests for different types of practitioners.

Key Screening Tools in U.S. Diabetic Foot Exams

Category	Tool/Method	Purpose
Visual Inspection	• Skin, nails, deformities, ulcers	Detects early signs of breakdown, infection, or structural risk
Neurological	• 10-g monofilament	Identifies loss of protective sensation (gold standard)
	• 128 Hz tuning fork	Assesses vibration perception (large-fiber neuropathy)
Vascular	• Pinprick/temperature testing	Detects small-fiber neuropathy
	• Pulse palpation (DP/PT)	Screens for peripheral arterial disease
	• Ankle-Brachial Index (ABI)	Quantifies arterial perfusion; confirms PAD
Risk Classification	• ADA 60-second foot exam	Structured checklist for rapid screening in primary care
	• IWGDF risk stratification	International guideline for ulcer/amputation risk categorization
Self-Screening	• Patient checklists/tools	Encourages at-home monitoring and early reporting of changes

Table 2 - Key Screening Tools in U.S. Diabetic Foot Exams

Clinical diabetic foot screening can also occur in multiple settings from primary care, diabetes education centres, podiatry clinics, mobile care to outpatient wound centres to name a few. Foot screening has not been widely adopted in diabetes education centres or with other modalities like optical coherence tomography (OCT) for diabetic retinopathy screening. This has led to fragmentation in care delivery and discrepancies in access to early preventative care. As risk is primarily based on a visual assessment, there is no consistency in the tools utilized and no standardization even within organizations. There are resource constraints in clinic settings, foot screening takes time, inadequate documentation and standardization.The tools we have available to us detect risk factors but are unable to detect which areas of the foot are truly at risk of tissue injury. This has led to a reactive approach to care.

When to Screen

Diabetics have a 25% lifetime risk of developing a foot ulcer. With 37 million people and only x vascular surgeons - it is also important to start screening patients at the appropriate times so the right patient is seen at the right time by the right clinicians. Screening has to occur so that the health system is not overwhelmed or stressed which means population screening of all diabetics with technology is not practical. It is recommended that l high risk populations should be the early target over all patients with diabetes. .

IIdentifying a high risk population according to the ADA and IDFU guidelines means that patients with previous ulceration and in remission, documented vascular changes and/or a neuropathic limb could be the first place to start with a routine and baseline screening exam. Approximately 4.5 - 7.7million people in the USA qualify as high-risk for diabetic foot complications (ADA; IWGDF guidelines).

Diabetic Foot Screening and the Inlow's 60-Second Tool

Diabetic foot complications represent a major source of morbidity, mortality, and healthcare expenditure worldwide. Ulceration and infection are common precursors to lower-extremity amputation, and their prevention is a central goal of diabetes management. The American Diabetes Association (ADA) emphasizes that systematic foot screening is essential for early detection of risk factors and timely intervention. According to the Standards of Care in Diabetes—2024, all adults with diabetes should undergo a comprehensive foot examination at least annually, with more frequent assessments for those at elevated risk, including individuals with peripheral neuropathy, peripheral arterial disease (PAD), foot deformity, or a history of ulceration or amputation (ADA, 2024).

ADA Screening Recommendations

The ADA outlines a structured approach to foot screening that includes:

- **Inspection:** Evaluation of skin integrity, nail health, callus formation, infection, or ulceration.
- **Neuropathy Testing:** Use of a 10-g monofilament supplemented by vibration, pinprick, or temperature sensation testing.
- **Vascular Assessment:** Palpation of pedal pulses and observation for ischemic signs such as dependent rubor or coolness.
- **Footwear Review:** Assessment of shoe fit and appropriateness to minimize trauma.

Patients identified as high risk should be screened every 3–6 months, while those with active ulceration or infection require urgent referral to specialized care.

The Inlow's 60-Second Diabetic Foot Screen

Complementing ADA recommendations, the Inlow's 60-Second Diabetic Foot Screen provides a rapid, standardized method for risk assessment that can be completed in approximately one minute. The tool evaluates integumentary and nail status, sensory function, vascular supply, musculoskeletal deformity, footwear appropriateness, and hallux mobility. Peripheral neuropathy is assessed through monofilament testing and patient-reported symptoms, while PAD is evaluated by pedal pulse palpation, temperature assessment, and observation of dependent rubor. Structural abnormalities such as bunions, Charcot arthropathy, or prior amputations are documented, alongside footwear suitability.
Risk stratification is achieved through a scoring system aligned with the International Working Group on the Diabetic Foot (IWGDF) classification. Scores determine recommended screening intervals:

- 0–6: annually
- 7–12: every six months
- 13–19: every three months
- 20–25: every one to three months

Patients with active ulceration, acute Charcot changes, or infection are categorized as urgent risk and require immediate referral.

Clinical Impact

The integration of ADA guidelines with practical tools such as the Inlow screen enhances the efficiency and consistency of diabetic foot care. Evidence suggests that early identification and management of risk factors can prevent up to 80% of diabetes-related amputations (Blanchette et al., 2023). The Inlow tool not only standardizes screening but also promotes interdisciplinary communication and patient education, reinforcing the ADA's emphasis on preventive care. Together, these approaches represent an evidence-based strategy to reduce morbidity and improve outcomes in diabetic foot management.

Objective Imaging Technology to assess the High Risk Diabetic Foot

The introduction of imaging technology that can look below the surface of the skin and see vascular and thermal changes before there is visual damage in the tissue of the foot. They have mainly been used to assess the wound, efficacy of treatments and the vascular interventions but are quickly moving into the pre-wound sector.

The two primary imaging modalities for both intact skin and wounded skin are thermography and multispectral imaging (tissue oximetry) for vascular assessments.

Thermography has been shown in RCT's to be a predictor of breakdown in the first 3 months post DFU healing. It has also been able to see early charcot changes and areas of infection guiding clinicians in the next step in investigations and care.

Tissue oximetry measures the microcirculation of the skin or the regional territories of perfusion of the foot. For the first time we are able to map the microcirculation in under 1 minute. Technology available to date has mainly been fiber based or probes on the skin which is not practical for widespread clinical adoption and therefore has been limited to scientific investigation.

Imaging is a perfect modality to assess the foot as it is objective and standardized. As an analogy, cancer screening, specifically mammograms (radiographic imaging) for at-risk women, has been able to reduce the mortality rates of breast cancer for women.

We need validated objective, technology-enabled imaging assessments that standardize care, document risk precisely, and support earlier intervention. MIMOSA represents the first available all in one technology to perform at risk screening.

Foot Assessment Using Thermography

Infrared thermography has emerged as a promising adjunctive technique for the assessment of the diabetic foot. By measuring infrared radiation emitted from the skin surface, thermography generates thermal maps that reflect underlying vascular and metabolic activity. Because temperature changes often precede visible tissue breakdown, thermography offers the potential for early detection of pathological processes such as ulceration, infection, and Charcot neuroarthropathy.

Principles and Methodology

Thermographic assessment involves capturing plantar or dorsal foot images under standardized environmental conditions. Patients are typically acclimatized to room temperature prior to imaging to minimize external variability. Thermal asymmetry between corresponding regions of the feet or between contralateral regions is considered clinically significant, with localized increases in temperature suggesting inflammation or infection, and cooler regions indicating ischemia or impaired perfusion.

Clinical Applications

Ulcer Prevention: Elevated focal temperatures may identify pre-ulcerative sites before skin breakdown occurs.

I**nfection Monitoring:** Thermography can highlight areas of increased metabolic activity consistent with cellulitis or osteomyelitis.

Charcot Neuroarthropathy: Asymmetrical thermal patterns between feet may indicate acute Charcot changes, warranting urgent referral.

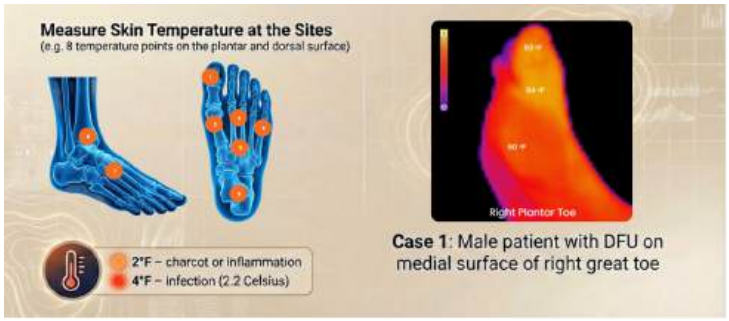
Adjunct to Screening Tools: When combined with structured instruments such as the Inlow's 60-Second Diabetic Foot Screen, thermography enhances sensitivity for detecting high-risk patients.

Recent studies have demonstrated the utility of digital infrared thermography in diabetic foot care.

Machine learning models applied to plantar thermograms have achieved high diagnostic accuracy, with reported specificity approaching 100% in distinguishing diabetic from non-diabetic populations (Castillo-Morquecho et al., 2024). Other investigations highlight its role in podiatric practice, where suspicious thermal distributions can guide further diagnostic testing and patient education (Plassmann, 2023; Petrova et al., 2024).

hermography is non-invasive, painless, rapid, and repeatable, making it suitable for routine clinical use. Its visual nature also facilitates patient engagement and education. However, interpretation requires standardized protocols, as results may be influenced by ambient conditions, footwear, or recent physical activity. At present, thermography is best regarded as an adjunct to established diagnostic methods rather than a standalone tool.

Figure 1- Thermography in DFU Assessment



Thermography represents an innovative approach to diabetic foot assessment, capable of identifying early pathological changes before clinical signs become apparent. When integrated into comprehensive screening protocols, it can improve risk stratification, guide timely interventions, and reduce the incidence of ulceration and amputation. Ongoing research, particularly in combining thermography with machine learning and digital health platforms, is likely to expand its role in routine diabetic foot care.

Foot Assessment Using Tissue Oximetry

Tissue oximetry, most commonly implemented via near-infrared spectroscopy (NIRS) or multispectral imaging, is an innovative modality for evaluating microvascular oxygenation in the diabetic foot. By quantifying relative concentrations of oxygenated and deoxygenated hemoglobin in superficial tissues, oximetry provides localized tissue oxygen saturation (StO_2) values that reflect perfusion and oxygen delivery to the tissue. This is clinically relevant in diabetes, where peripheral arterial disease (PAD) and microvascular dysfunction are major contributors to ulceration, impaired healing, and amputation risk (Ubbink & Koelemay, 2021; Frykberg et al., 2022).

Principles and Methodology

NIRS applies near-infrared light to penetrate skin and subcutaneous tissue to several millimeters, with spectral absorption differences between hemoglobin states used to estimate StO_2. Measurements are typically obtained at standardized plantar and dorsal sites with bilateral comparisons and serial readings used to identify asymmetries or trends. Multispectral imaging systems acquire spatially resolved spectra to compute tissue oxygenation maps of the tissue. Declines in StO_2 or asymmetric distributions suggest localized perfusion compromise (Khaodhiar et al., 2007; Yudovsky & Pilon, 2010).

Clinical Applications

- **PAD detection and triage:** Reduced StO_2 complements ankle-brachial index (ABI) and toe-brachial index (TBI), aiding detection of microvascular impairment when macrovascular indices are equivocal.
- **Ulcer risk stratification:** Persistently low StO_2 at high-pressure or callused regions indicates vulnerability to breakdown and delayed healing.
- **Monitoring revascularization:** Serial oximetry captures perfusion improvements post-intervention, supporting clinical decision-making.
- **Adjunct to structured screening:** Integrated with tools such as Inlow's 60-Second Diabetic Foot Screen, oximetry enhances identification of high-risk patients by adding objective perfusion data.

Evidence Base

Clinical studies demonstrate that tissue oximetry can discriminate impaired microvascular function in diabetes and predict wound-healing potential. Hyperspectral tissue oximetry has been shown to identify areas at elevated risk for ulcer development before overt tissue breakdown (Khaodhiar et al., 2007). NIRS-based approaches correlate with clinical improvement after revascularization and can reveal microvascular deficits despite normal ABI/TBI, highlighting added value for comprehensive foot assessment (Neidrauer et al., 2010).

Advantages and Limitations

Tissue oximetry is non-invasive, painless, portable, and provides real-time quantitative perfusion metrics suitable for outpatient and bedside use. Its visual outputs (maps or trends) support patient education and interdisciplinary communication. Interpretation requires standardized protocols, as readings can be affected by probe placement, skin pigmentation, edema, temperature, and ambient light. At present, oximetry should be considered complementary to established vascular assessments rather than a replacement.

Tissue oximetry offers clinically meaningful insight into microvascular oxygenation and perfusion in the diabetic foot, enabling earlier identification of ischemic risk, more precise stratification, and objective monitoring of vascular therapies. When embedded within comprehensive screening protocols, it can guide timely interventions and help reduce ulceration and amputation rates.

Future Directions in Diabetic Foot Screening

Despite advances in guideline-based screening and structured tools, diabetic foot complications remain a significant global burden. Future directions in foot assessment will likely involve the integration of traditional risk stratification methods with novel imaging and perfusion technologies, supported by digital health platforms and artificial intelligence.

Integration of Guideline-Based and Technology-Enhanced Screening

The American Diabetes Association (ADA) and the International Working Group on the Diabetic Foot (IWGDF) provide evidence-based frameworks for risk stratification, while tools such as the Inlow's 60-Second Diabetic Foot Screen offer rapid, standardized clinical assessments. Emerging modalities—including infrared thermography and tissue oximetry—add objective, quantitative data on inflammation, perfusion, and microvascular oxygenation. Future screening protocols will likely combine these approaches, creating hybrid models that improve sensitivity and specificity for early detection see Table 3).

Digital Health and Remote Monitoring

Advances in portable imaging devices, smartphone-linked sensors, and cloud-based analytics will enable remote foot monitoring outside of traditional clinical settings.

Table 3 - Evolution of Thermography and Oximetry for DFU Assessment

Thermography	NIRS
• The International Working Group on the Diabetic Foot (IWGDF, 2023) practical guidelines endorse use of foot temperature monitoring as part of prevention in people at high risk for DFU (Araujo et al, 2022; Lazo-Porras et al, 2016). • IWGDF's 2023 Charcot neuro-osteoarthropathy guideline specifically recommends considering infrared thermometry to measure skin temperature and compare both feet when Charcot is suspected (IWGDF, 2023). • Thermometry is now recommended in clinical practice guidelines for high-risk patients with diabetes from the following authorities: The International Workgroup on the Diabetic Foot, The Wound Healing Society, and The American College of Foot and Ankle Surgeons (Podimetrics, 2022).	Recent reviews of diabetic foot ulcer (DFU) imaging underscore NIRS as a well-established technology that shows promise in predicting healing outcomes in diabetes-related foot ulcers (González-Villacorta et al, 2025).

Patients may be empowered to perform self-assessments using thermographic or oximetric devices, with data transmitted to clinicians for early intervention. This aligns with broader trends in telemedicine and chronic disease management, expanding access to high-quality foot care.

Artificial Intelligence and Predictive Analytics

Machine learning algorithms applied to thermographic and oximetric datasets have already demonstrated high accuracy in distinguishing diabetic from non-diabetic populations and predicting ulcer risk. Future research will focus on predictive models that integrate clinical, imaging, and perfusion data to identify patients at imminent risk of ulceration or amputation. Such models could guide personalized screening intervals and targeted preventive interventions.

Interdisciplinary Care Pathways

The future of diabetic foot screening will also emphasize interdisciplinary collaboration. Endocrinologists, podiatrists, vascular specialists, wound care nurses, and digital health experts will need to work together to validate new technologies, establish standardized protocols, and ensure equitable implementation across diverse healthcare systems.

Conclusion

Future directions in diabetic foot screening point toward a multimodal, technology-enhanced approach that integrates guideline-based risk stratification with objective imaging and perfusion assessment. By combining structured tools such as the Inlow screen with thermography, tissue oximetry, and AI-driven analytics, clinicians will be better equipped to detect risk earlier, personalize care, and reduce the global burden of diabetic foot disease.

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