Remote Temperature Monitoring in Diabetic Foot Ulcer Detection

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Introduction

Diabetic foot ulcers (DFUs) are associated with increased morbidity, mortality, and resource utilization [1-3]. Thermometry has been found effective for the early detection and, when used to prompt timely non-invasive intervention such as pressure offloading, prevention of recurrent DFU [5-7]. A thermometric smart foot mat for the home* is available for remote monitoring of plantar foot temperatures. A recent investigation suggests that this smart foot mat may detect the inflammation preceding a DFU on average 5 weeks prior to clinical presentation [4].

This case series details 3 veterans with h/o DFU, elevated HbA1c, and peripheral neuropathy who were followed in the Podiatry PAVE (Preventing Amputations for Veterans Everywhere) Clinic. These veterans were prescribed the smart mat for remote thermometric monitoring of the feet as an adjunct to standard preventative foot care.

Methods

Veterans followed at the PAVE Clinic are issued a mat if meeting at least 3 of the following: h/o DFU, peripheral neuropathy, h/o amputation, foot deformity, or impaired vascular status. Veterans are instructed to use the mat daily and to continue standard preventative foot care.
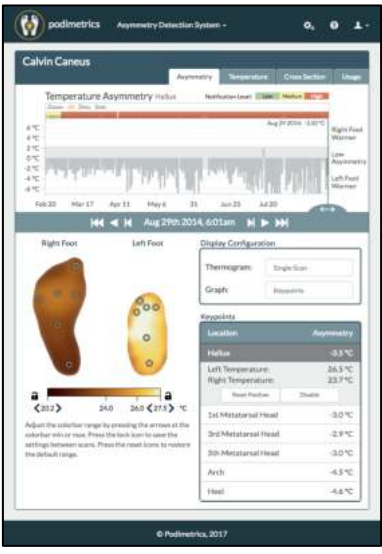
The thermometric data collected by the mat are referred to as scans and are securely transmitted and accessed. Clinical staff can access de-identified foot temperature maps, or thermograms, derived from the scans through an online physician portal for triage.
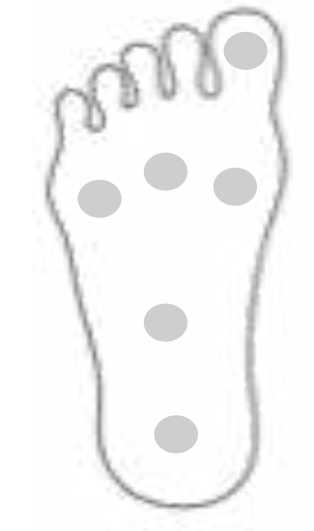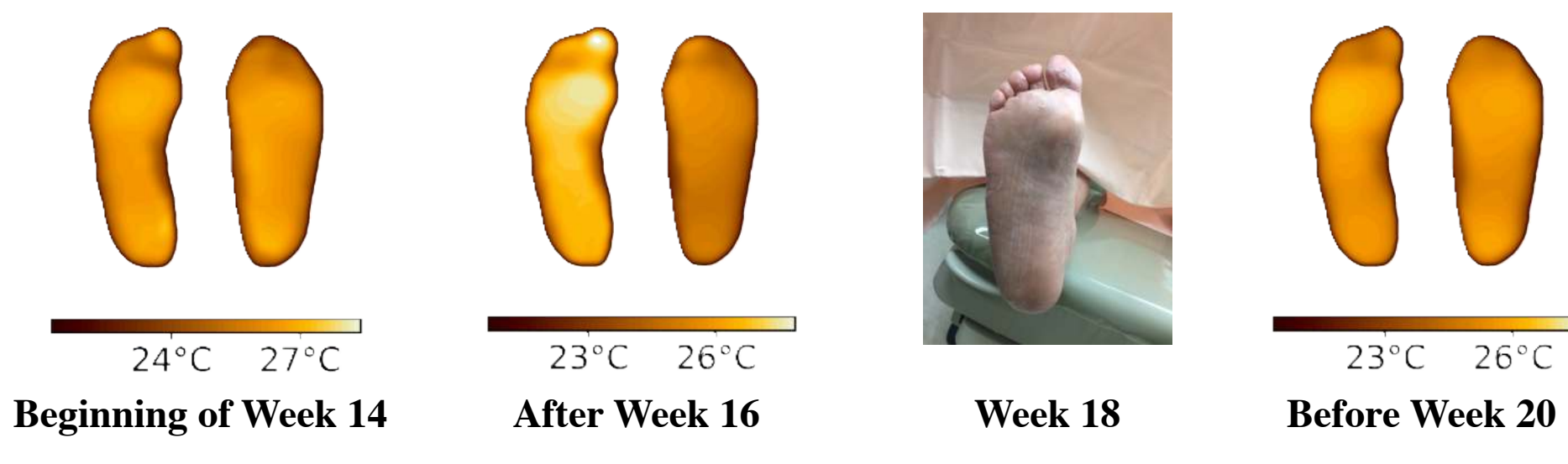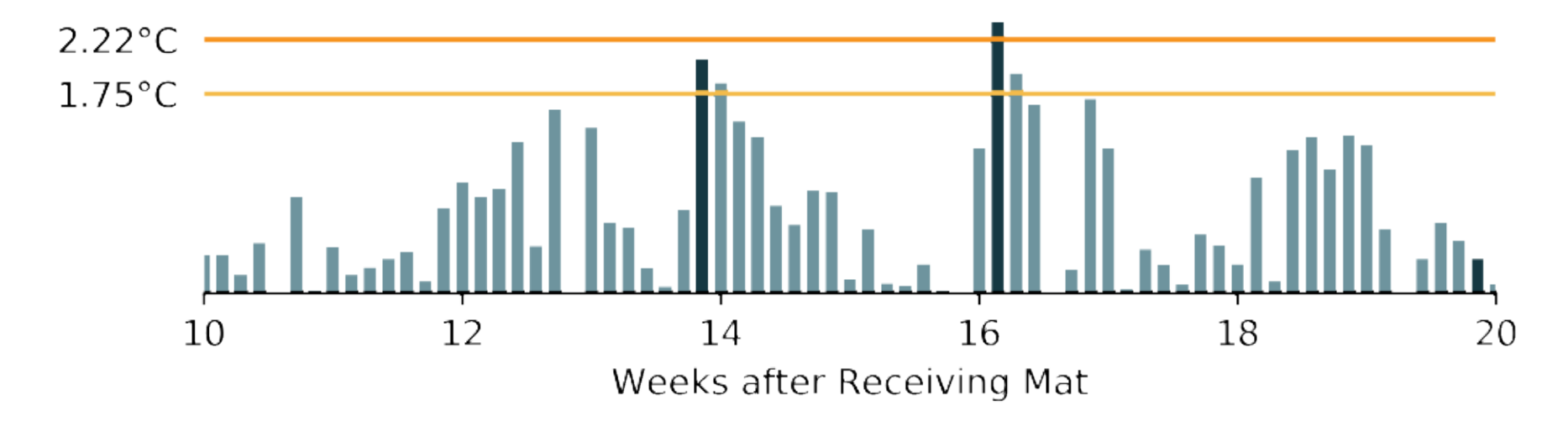
The temperature data collected by the mat are automatically analyzed for temperature differences, or asymmetry, between the left and right feet at six locations consistent with the approach most common in the literature [5-7].

⚠️ **>1.75°C**

A veteran with temperature asymmetry exceeding 1.75°C over two or more consecutive uses at the same location triggers a notification to the clinical staff, after which the veteran is considered "in episode." A phone call is made to the veteran to encourage proper offloading, decreased walking, elevation of feet, and visual exam at home.
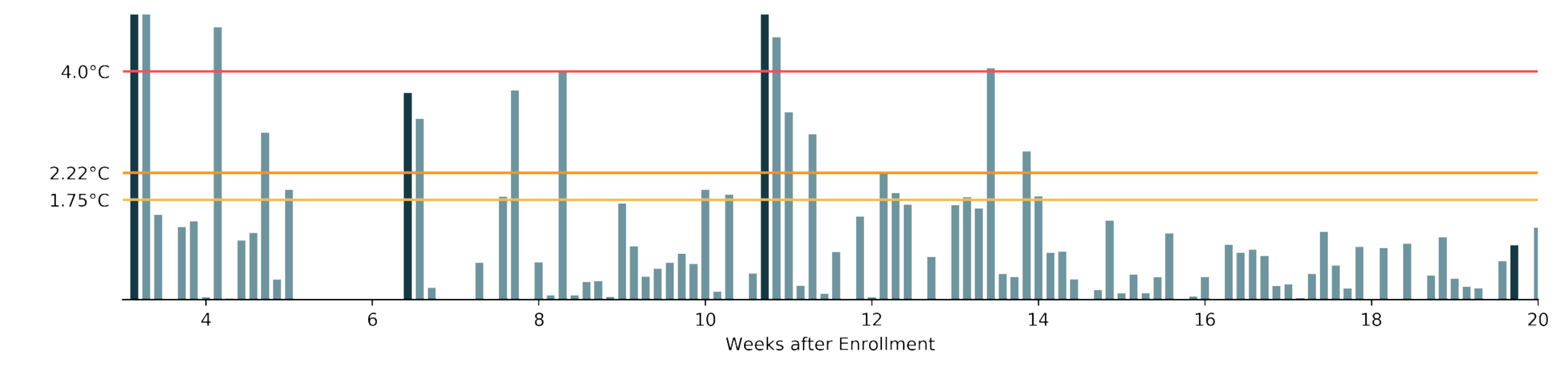
Podimetrics RTM System, Podimetrics, Inc., Somerville, MA

Case 1

Temperature chart: Weeks after Receiving Mat (10 to 20), with reference lines at 2.22°C and 1.75°C

| Beginning of Week 14 (24°C–27°C) | After Week 16 (23°C–26°C) | Week 18 | Before Week 20 (23°C–26°C) |

- 67 year old male veteran with IDDM2 (HbA1c 8.5%), neuropathy, gout, hypertension, hyperlipidemia, osteoarthritis, and coronary artery disease.

- Veteran has extensive DFU history, including several wounds to left distal 3rd digit, with most recent healing 2 years prior to veteran receiving mat, and a wound to the right distal 2nd digit for which a distal Symes amputation was performed, secondary to osteomyelitis, one year prior to veteran receiving mat.

- Fourteen weeks after receiving the mat, veteran entered an episode with temperature asymmetry of 2.1°C at the right hallux. During a call prompted by the notification, veteran denied any plantar lesions. Upon clinical exam a week later, no wounds found. Plastizote accommodative orthotics were given.

- A second phone call was made during week 16 for continued elevated asymmetry of 1.8°C at the right hallux. The veteran was seen in clinic five days later without DFU. A callus to the distal left 3rd digit was pared without incident.

- **Despite a history of multiple wounds and literature suggesting that 50% of patients who heal from a DFU suffer recurrence within two years [4], veteran has remained DFU free in the 34 weeks since receiving the mat.**

Case 2

Temperature chart: Weeks after Enrollment (4 to 20), with reference lines at 4.0°C, 2.22°C and 1.75°C

- 80 year old male veteran with IDDM2 (HbA1c 7.7%), neuropathy, hypertension, hyperlipidemia, and h/o right plantar hallux wound which healed 9 months prior to receipt of mat.

- Veteran enters episode 3 weeks after receiving mat with temperature asymmetry of 6.0°C and 8.2°C on two consecutive days. Remote education given to decrease walking and use appropriate footwear. One week later, the veteran remained in episode with asymmetry of nearly 4.7°C at the right foot.

- Veteran presented to clinic 3 days later with a pinpoint DFU to the plantarmedial right hallux IPJ post-debridement. A custom offloading orthotic was ordered to fit his diabetic shoes.

- Between weeks 6 and 7, the veteran was found with temperature asymmetry exceeding 3°C, alternating right to left. Upon exam during a clinic visit at the end of week 7, the veteran's right IPJ wound was found healed.

- Despite this, the veteran remained in episode through week 11, with temperature asymmetry exceeding 6.0°C to the right forefoot and hallux. Veteran presented to clinic at the end of week 11 wearing sandals with no offloading. A pre-ulcerative callus to the area of concern was noted. Upon debridement, the plantarmedial hallux IPJ showed appearance of deep tissue injury. The veteran was reminded of the importance of offloading, and metatarsal bars were added to the veteran's sandals. The veteran was casted for custom orthotics with sweet spot at the hallux IPJ.

- **The veteran's asymmetry episode resolved shortly thereafter, and he has remained free from asymmetry episode and DFU free for the last 22 weeks. Early detection due to monitoring for temperature asymmetry may have resulted in an early intervention, potentially shortening wound course.**

| Week 3 (17°C–20°C) | During Week 6 (19°C–22°C) |
| Week 11 (20°C–23°C) | Before Week 20 (24°C–27°C) |
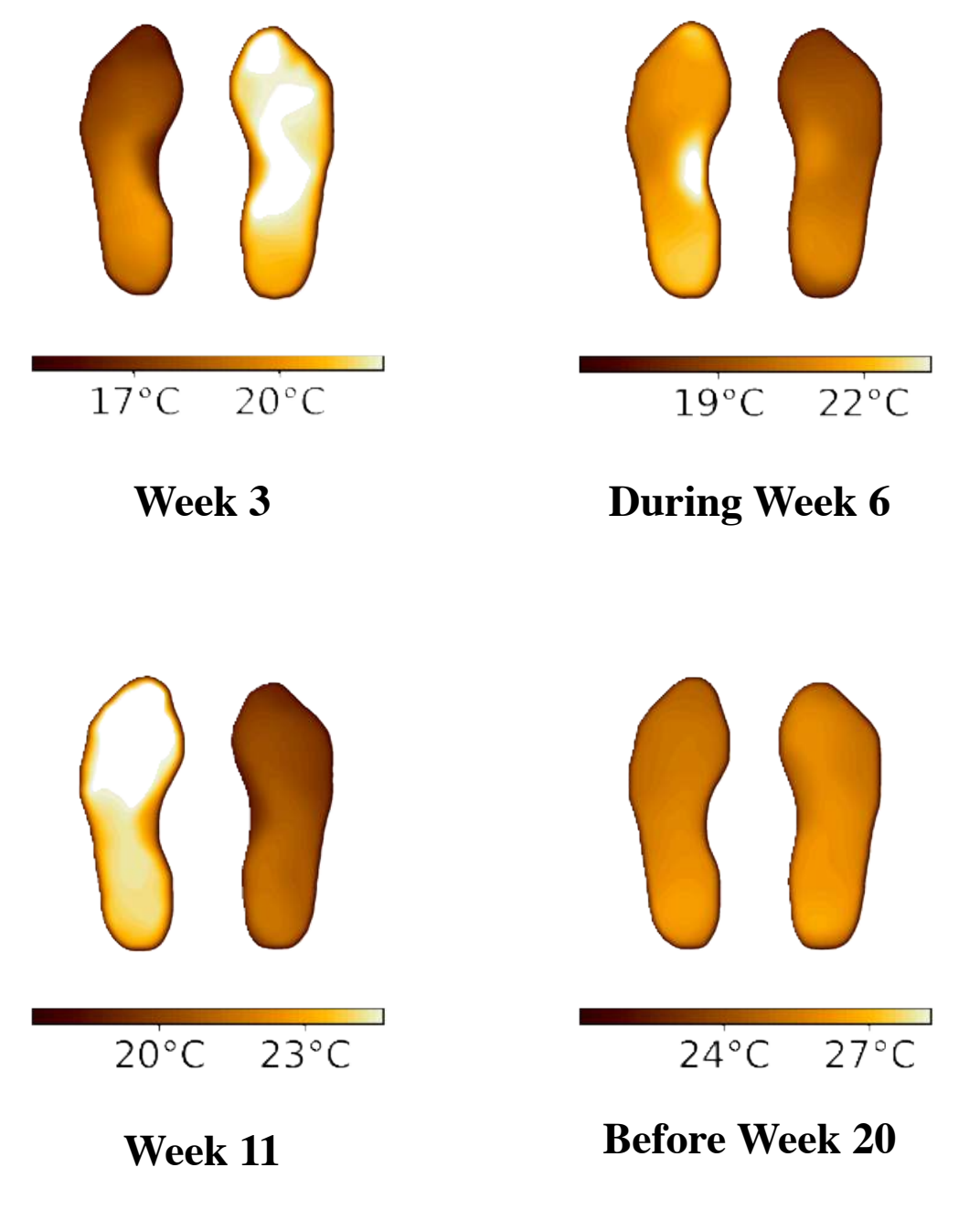
Case 3

- 69-year-old male veteran with IDDM2 (HbA1c 12.3% two months prior to receiving mat, 11.0% two months after receiving mat), neuropathy, hypertension, hyperlipidemia, and peripheral vascular disease.

- Veteran has h/o DFU at right plantar TMA stump, most recently healed three weeks prior to receipt of mat.

- Patient entered asymmetry episode on day 1. Patient in episode for following two weeks and presented to clinic with DFU. Veteran denied prior knowledge of wound.

- Continued offloading and wound care resulted in closure approximately 9 months after receiving the mat.

- **The episode's evolution suggests DFU may have been developing prior to day 0. The DFU recurred despite normal physical exam by the care team only weeks prior, and was identified by the mat prior to the patient or care team becoming aware of pathology.**

| On Day 1 (16°C–19°C) | On Day 14 |
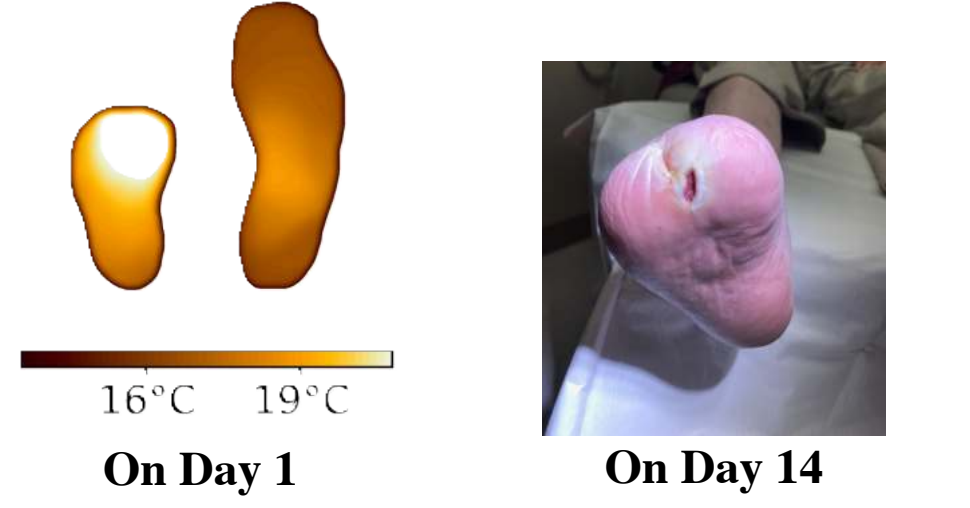
Conclusion

Three high-risk patients with h/o DFU, poorly-controlled diabetes, and peripheral neuropathy were followed with a remote temperature monitoring mat. In all three cases, use of the mat resulted in early identification inflammation and prompted clinical evaluation and intervention. This practice observation is consistent with previous literature suggesting daily foot temperature monitoring may prevent as many as 70% of developing DFU [5-7]. Importantly, both reductions in DFU days or incidence may have considerable impact on morbidity, mortality, and resource utilization.

References

[1] Morbach S, et al. Long-Term Prognosis of Diabetic Foot Patients and Their Limbs Amputation and Death over the Course of a Decade. Diabetes Care, 2012. [2] Rice JB, et al. Burden of Diabetic Foot Ulcers for Medicare and Private Insurers. Diabetes Care, 2014. [3] Armstrong, DG. The Big Picture 2015: Lower Extremity Complications of Diabetes. Diabetic Foot, 2015. [4] Frykberg RG, et al. Feasibility and Efficacy of a Smart Mat Technology to Predict Development of Diabetic Plantar Ulcers. Diabetes Care, 2017 [5] Lavery LA, et al. Home Monitoring of Foot Skin Temperatures to Prevent Ulceration. Diabetes Care, 2004. [6] Lavery LA, et al. Preventing Diabetic Foot Ulcer Recurrence in High-Risk Patients: Use of Temperature Monitoring as a Self-Assessment Tool. Diabetes Care, 2007. [7] Armstrong DG, et al. Skin Temperature Monitoring Reduces the Risk for Diabetic Foot Ulceration in High-Risk Patients. The American Journal of Medicine, 2007.

Acknowledgements