

Implementation of a Remote Temperature Monitor for the Prevention of Diabetic Foot Ulcers

A Case Series of 5 Patients

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Introduction

Diabetic Foot Ulcers (DFU) are known to be preceded by clinical or sub-clinical inflammation, for which increased temperature is a surrogate marker. Once-daily monitoring of plantar foot temperature has previously been demonstrated to be effective for preventing DFU when used to prompt timely, non-invasive interventions such as pressure offloading of the affected region of the foot [1-3].

An in-home, telemedicine, thermometric mat (the Podimetrics System) has recently been studied as part of a multi-center cohort trial to assess its usability and predictive accuracy [4-5]. The investigators found that the Podimetrics System is capable of detecting up to 97% of non-acute plantar DFU approximately 5 weeks before clinical presentation, making it suitable for remote monitoring and real-time risk-stratification of patients. We have implemented this system in a veteran population as a tool for primary and secondary DFU prevention.

Objective

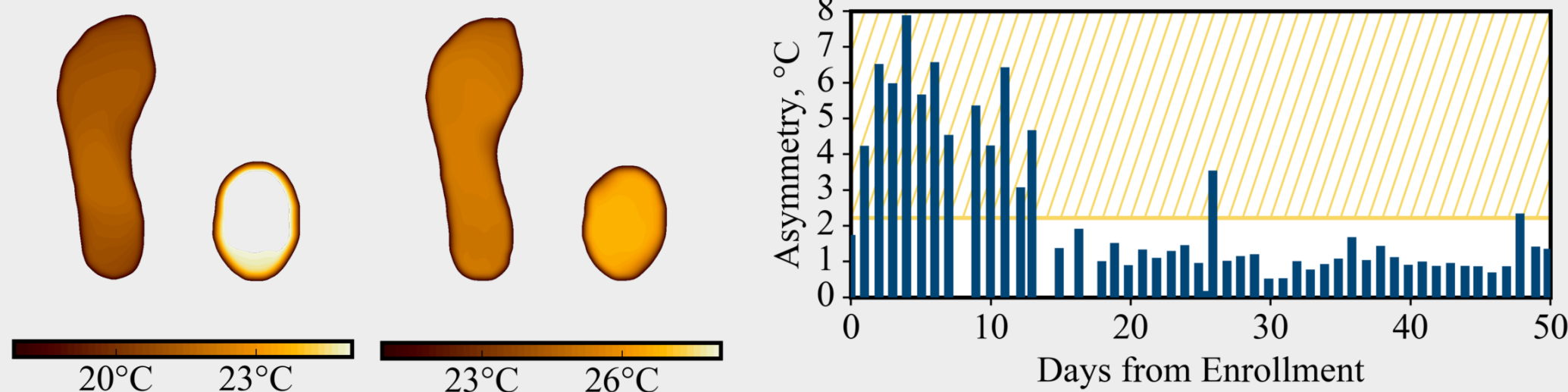
The objective of this study was to explore how the inflammation preceding and accompanying different pathologies in the diabetic foot present within plantar "thermograms," which are two-dimensional temperature images captured automatically by the Podimetrics System. We hypothesize that these thermograms, which are a novel aspect of the system, may provide helpful clinical context for evaluating patients at-risk for inflammatory foot diseases such as DFU.

Methods

We present a case series of five veterans, each of whom has been prescribed the Podimetrics System and each of whom subsequently presented with a hotspot episode in early 2017. Each has history of diabetes mellitus and neuropathy.

Consistent with previous research [1-3], we assess patient risk by considering temperature differences between six contralaterally-matched locations on the left and right plantar foot surfaces: the hallux, first, third, and fifth metatarsal heads, arch, and heel. If the temperature difference at one or more location exceeds 2.2 degrees Celsius (4 degrees Fahrenheit) over two or more consecutive scans, the veteran is deemed to have a "hotspot" and is instructed to reduce step-count by 50% for a week. In response to a persistent hotspot or at the discretion of the clinician, a patient is referred to schedule an appointment for foot examination.

Patient 1



- 61 y/o veteran with h/o of left Chopart amputation notable for a slow healing time-course and dehiscence at the incision.

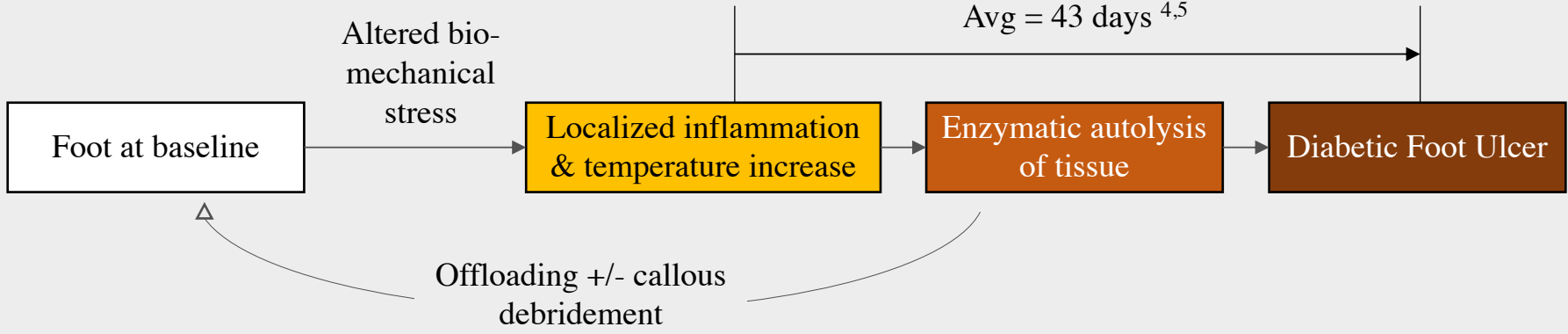
- Veteran prescribed Podimetrics System and promptly presented with hotspot with large absolute temperatures (> 8.0 deg C at peak asymmetry) over entirety of stump.

- Veteran called to offload, which resulted in immediate reduced temperature asymmetry, and hotspot episode resolved after seven days w/o new asymmetry.

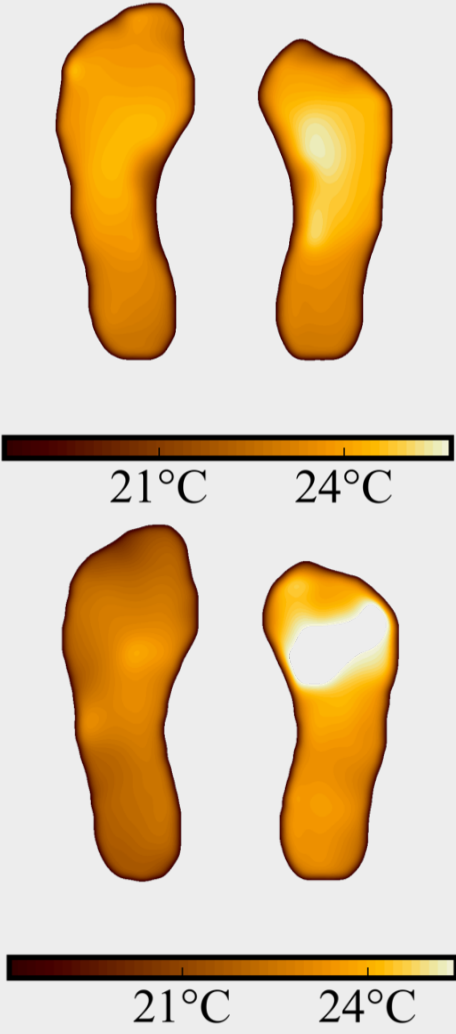
- In the patient's next clinical exam approximately three weeks later, no wounds were found on stump (although hyperkerotosis was debrided from the right forefoot).

- The patient has remained free of hotspots and DFU in the month since the initial episode at enrollment.

Thermometric Model of Ulcer Development



Patient 2



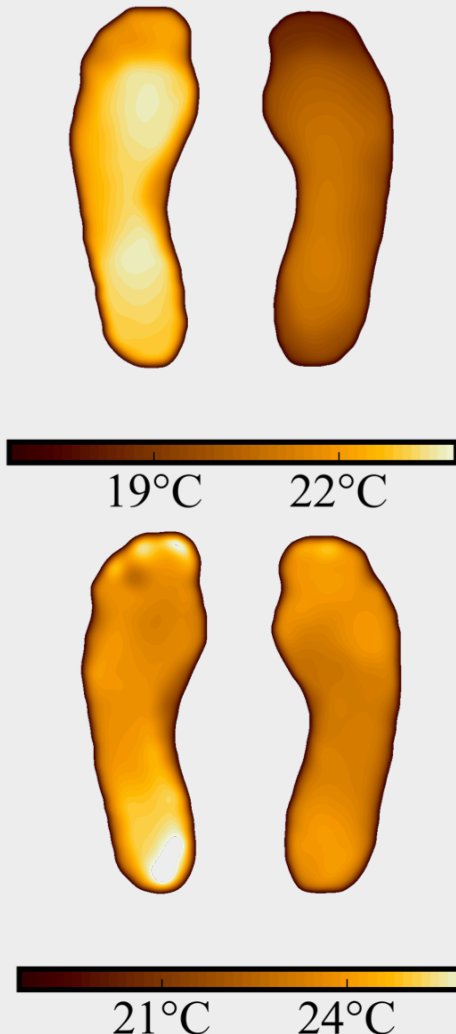
- 75 y/o veteran s/p recently healed left sub-2nd MTPJ DFU evaluated in clinic for recurrent callous at same site. Veteran prescribed Podimetrics System at this visit.

- Approximately three weeks later, veteran presents for hotspot at third metatarsal. Thermogram suggests large inflammation ($\Delta T > 6^{\circ}\text{C}$) across the medial sub-MTPJ regions.

- Thick hyperkerotosis noted on exam at left sub-2nd MTPJ. Upon debridement, a 2cm x 2cm x 0.4 cm granular wound was noted with macerated edges free from infection and erythema

- Superficial wound unhealed at veteran's most recent exam. Patient instructed to use cam walker and reduce activity.

Patient 3



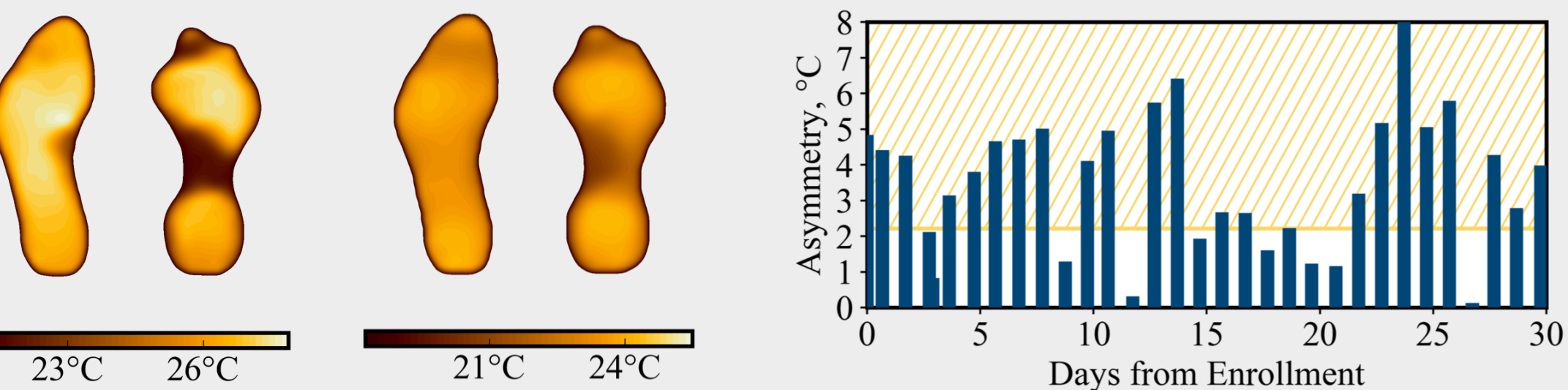
- 60 y/o veteran prescribed Podimetrics System after being seen in clinic for ingrown nail on the right hallux, which was trimmed during exam.

- After two weeks of use, the veteran presented with a hotspot and is called to offload and make an appointment. The hotspot had a maximum temperature asymmetry of 3.7°C at the hallux and is notable for diffuse asymmetry across entirety of the right foot.

- During exam seven days later, patient found to have paronychia on the lateral border of the right hallux, for which a nail avulsion was performed.

- Patient has remained free of hotspots since, and during the patient's most recent office visit more than a month after initial hotspot detected, the nail bed was found to be healed.

Patient 4



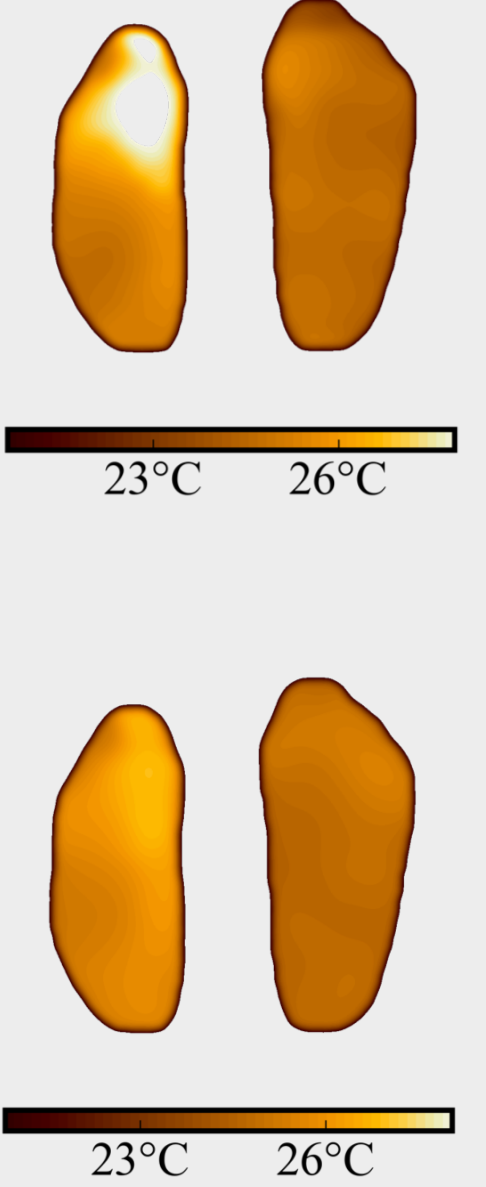
- 88 y/o veteran with h/o hyperkerotosis at left sub-2nd MTPJ subsequently prescribed Podimetrics Mat.

- Veteran presented immediately with large hotspot ($\Delta T > 6^{\circ}\text{C}$) measured at arch due to cold region across medial sub-MTPJs of left foot.

- Patient seen in clinic on day 15 with recurrent hyperkeratosis at sub-2nd MTPJ requiring debridement.

- Patient's large hotspot subsided over subsequent 10 days ($\Delta T < 2^{\circ}\text{C}$ on average), although asymmetry has recently escalated just prior to preparation of this poster.

Patient 5

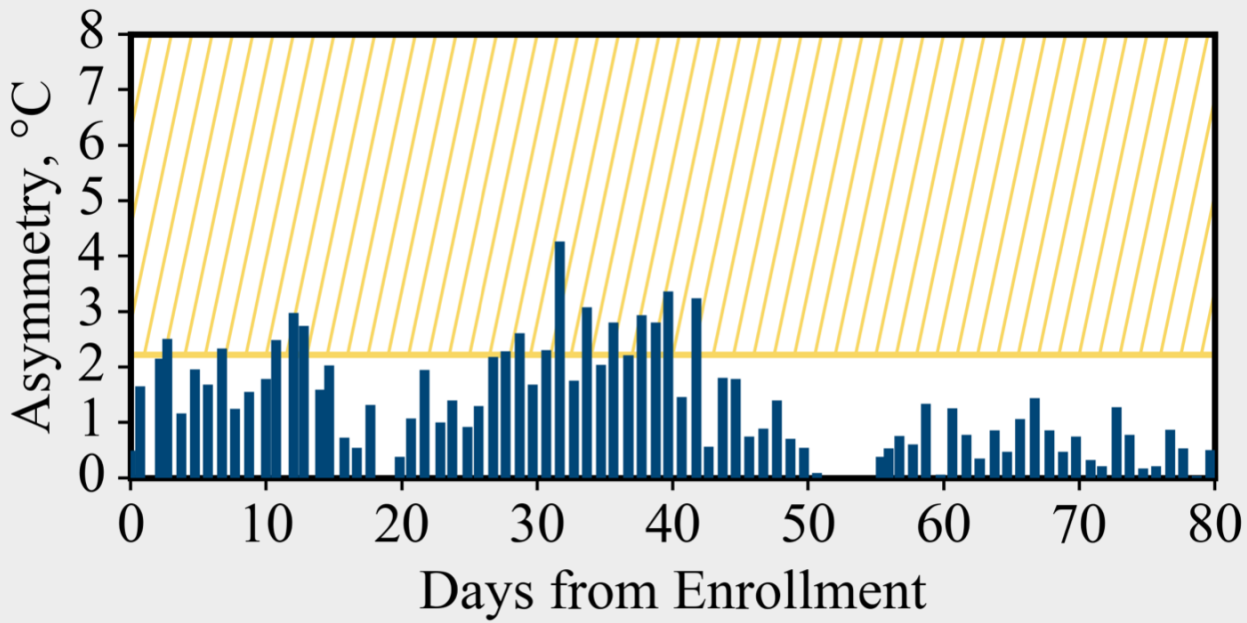


- 64 y/o veteran with h/o diffuse b/l sub-hallux hyperkerotosis resulting in right foot DFU measuring $0.3 \times 0.3 \times 0.1$ cm. Wound epithelized 4 days prior to receiving Podimetrics System.

- After approximately two weeks of using device (day 13), patient presents with hallux hotspot ($\Delta T = 2.8^{\circ}\text{C}$) and localized inflammation visible on the thermogram. Veteran asked to offload and schedule appointment for clinical exam (next scheduled appointment > 2 months later). Veteran reported he was unaware of any changes in his feet.

- Diffuse hyperkerotosis noted on exam on day 25. Debridement revealed a superficial wound measuring $0.2\text{cm} \times 0.3\text{cm}$ absent of malodor and drainage. Wound was dressed with Betadine.

- Wound epithelized as of day 60, and patient has remained free of DFU and hotspots in the five months since initial resolution on day 50.



Conclusion

A series of five cases demonstrates the ways in which inflammation presents on thermograms captured by a novel thermometry system for primary and secondary prevention of DFU. Important observations include:

- The affected region may be colder than contralaterally-matched region (Case 4)
- Inflammation due to infection may distribute diffusely across the affected foot (Case 3).
- Ulcers detected via thermometry often present as hyperkerotosis (Cases 2 and 5).
- Hotspots may resolve quickly in some cases due to offloading (Case 1) or debridment of pre-ulcerative lesions (Case 4), and as a result, thermometry may be used to remotely monitor the effectiveness of interventions.
- Day-to-day asymmetry may be volatile, even in cases where ulceration is imminent (Cases 4 and 5).

The availability of thermograms may provide useful clinical context to guide early preventative care and interventions for patients presenting with hotspots.

References

[1] Lavery LA, Higgins KR, Lancot DR, Constantinides GP, Zamorano RG, Armstrong DG, Athanasiou KA, Agrawal CM. Home monitoring of foot skin temperatures to prevent ulceration. *Diabetes care* 2004;27(11):2642-7. [2] Lavery LA, Higgins KR, Lancot DR, Constantinides GP, Zamorano RG, Athanasiou KA, Armstrong DG, Agrawal CM. Preventing Diabetic Foot Ulcer Recurrence in High-Risk Patients Use of temperature monitoring as a self-assessment tool. *Diabetes care*. 2007 Jan 1;30(1):14-20. [3] Armstrong DG, Holtz-Neiderer K, Wendel C, Mohler MJ, Kimbriel HR, Lavery LA. Skin temperature monitoring reduces the risk for diabetic foot ulceration in high-risk patients. *The American journal of medicine*. 2007 Dec 31;120(12):1042-6. [4] Frykberg RG, Rothenberg GM, Fitzgerald RH, Cazzell SM, Najafi B, Reyzelman AM, Gordon IL, Bloom JD, Linders DR, Petersen BJ, Nouvong A. An automated home monitor for the early detection of diabetic foot ulcers. *Diabetes*. 2016; 64 (suppl 1): A36. [5] Frykberg RG, Rothenberg GM, Fitzgerald RH, Cazzell SM, Najafi B, Reyzelman AM, Gordon IL, Bloom JD, Linders DR, Petersen BJ, Nouvong A. Abstract 141-OR/141. An automated home monitor for the early detection of diabetic foot ulcers. Presented at: ADA 76th Scientific Sessions; June 10-14, 2016; New Orleans, LA.