Paradigm Shift for Diabetic Foot Ulcers: A Closer Look at Prevention

Suggested Running Head: Diabetic Foot Ulcer Prevention

Gary M. Rothenberg, DPM, CDE, CWS

Clinical Assistant Professor, Internal Medicine

University of Michigan School of Medicine

Ann Arbor, Michigan

24 Frank Lloyd Wright Drive

Domino's Farms Suite 1300 MEND

Ann Arbor, Michigan 48106*

*address of correspondence

(734) 232-2252 phone

(734) 232-9240 fax

gmrdpm@med.umich.edu

Jaclyn B. Marino, DPM, DrPH, MPH, DABPM, FACFAOM

Attending Podiatrist / Assistant Director of Resident Education

Carl T. Hayden VA Hospital

650 East Indian School Road

Phoenix, Arizona 85012

Dr. Rothenberg serves as a Consultant Medical Director for Podimetrics. There was no financial compensation for preparation of the manuscript.

Purpose

The purpose of this perspective in practice is to characterize the burden of diabetic foot ulcers and review the established mechanisms for preventing this significant complication. Two detailed case examples will demonstrate the value of prevention.

Methods

Using two cases of high-risk diabetic foot patients as thoughtful examples, a review of prevention of diabetic foot ulcers is included focusing on several key position statement papers. Diabetic foot ulcer prevention strategies from the provider and patient perspective are summarized. Both case presentations are in high-risk patients – one is managed successfully with the recommended preventive strategies while the other has a less ideal outcome.

Results

The burden of diabetic foot ulcers is tremendous, and recurrence is a significant problem. Patients who have previously experienced foot ulceration are at for re-ulceration, hospitalization, and amputation. Compared to treatment of diabetic foot ulcers, very little research is dedicated to either primary or secondary prevention of foot ulcers. Proven strategies for prevention include foot education, patient daily self-examinations, prescription shoes and inserts, routine care by a foot care specialist / podiatrist, and temperature monitoring. As with many therapies, adherence plays a role in success of these techniques, especially in high risk patients.

Conclusions

Despite the high incidence of diabetic foot ulcerations, up to 75% of foot ulcers may be preventable. According to the literature, the most effective strategies to prevent diabetic foot ulcers include routine

foot care and evaluation by podiatrists or nurses, daily foot self-examinations, adherence to therapeutic shoes and inserts, and temperature monitoring.

The morbidity and mortality associated with foot ulceration among people with diabetes is well established. Diabetic foot ulcerations (DFU) represent a common and costly complication of diabetes[1]. It is estimated that lifetime incidence of developing a foot ulceration is 15-25%[2]. It is also reported that greater than 50% of ulcers will become infected and in the presence of infection, 20% will progress to develop osteomyelitis and result in subsequent amputation. In the US alone, these statistics equate to approximately 1.5 million new ulcers and 92,000 amputations per year[3]. Risk factors for development of diabetic foot ulcers include peripheral neuropathy, foot deformity, duration of diabetes, and peripheral arterial disease[4]. Another significant problem associated with DFUs is the high recurrence rates. Within the first year after healing a DFU, several studies suggest incidence of recurrence is between 30 and 40 percent[2]. Given the sobering statistics associated with diabetic foot ulcers, an area of strong focus for at-risk patients should be education on prevention of this devastating complication. The purpose of this perspective in practice is to review the current evidence based medicine associated with diabetic foot ulcer prevention highlighting the modalities of known success and identifying barriers to daily implementation. Case examples will be given to demonstrate the value of ulcer prevention.

The burden of wound care is extraordinary, both for the patient and the health care system yet historically, there is little attention given to prevention. Bus and colleagues reported that in Europe, for every euro spent on ulcer prevention, ten are spent on ulcer healing. Similarly, in the research market arena, for every randomized clinical trial conducted on prevention, ten are conducted on healing[5]. It seems natural that future directions in this field should emphasize DFU prevention.

Case Example: The Value of Prevention

An 84-year-old male with longstanding diabetes, peripheral neuropathy and Charcot arthropathy was followed routinely in a high-risk foot clinic. He had a history of left plantar 1st metatarsal ulceration and multiple pre-ulcerative calluses to bilateral feet. He was followed every 2 months for routine care and was adherent with consistent use of depth inlay shoes and custom insoles. Due to high-risk status, he was issued a remote temperature monitoring system and asked to use it daily. Three months after receiving the mat, asymmetry of 8 degrees was noted to the left foot and he was called in for a visit where edema and warmth was noted. Radiographs were negative and no wounds were noted. A presumptive diagnosis of acute Charcot flare was given and he was placed in total contact casts weekly for 3 weeks when skin temperatures were symmetric and edema resolved. He was transitioned back to appropriate footwear. He continued with shoes and daily thermometry and 2 months later, asymmetry was once again noted via remote temperature monitoring. He returned to the clinic and upon debridement of a pre-ulcerative callus plantar 1st metatarsal head, a superficial ulceration was noted. The lesion was treated with local wound care and offloading and resolved without complication in 4 weeks. A decision was made by the clinical staff to increase frequency of preventative care to every 6 weeks and he has remained wound free for 18 months.

A 56-year-old male with Type 2 diabetes and multiple toe amputations was followed in a high-risk foot clinic. Under urgent circumstances for infection, he underwent a left transmetatarsal amputation. The surgical foot healed without complication and he was ready for custom orthotics and shoes by post-op week six. While waiting for his shoes, the patient decided to wear his old athletic style shoes and developed a blister to the plantar central TMA. Despite advanced wound care modalities, the wound has failed to heal after 7 months. The patient has been intermittently adherent with offloading

recommendations. He has developed cellulitis of the foot and leg twice during the 7 months with both episodes failing outpatient oral antibiotics and requiring hospitalization.

DFU Morbidity, Mortality and Cost

Wound care is time consuming and wearing offloading shoes and boots can be inconvenient. Often, time lost from work and overall decreased quality of life for the patient or a caregiver can be significant. It is well known that 85% of diabetes related lower extremity amputations are preceded by non-healing ulcerations[6]. Previous reports cite five-year mortality rates among patients with diabetes who experience amputations at 47%. Mortality rates in unique cohorts such as veterans with diabetes have been reported as high as 56%[7]. These mortality rates are significantly higher than commonly thought of conditions such as breast and prostate cancers.

Ulcerations that become infected may lead to hospitalization and an increased burden to already overburdened healthcare systems. The majority of healthcare dollars in diabetes lower extremity related complications are spent on inpatient management. Therefore, it is incumbent upon healthcare practitioners to avert wound recurrence and avoid hospitalizations, if at all possible. If ulceration is the most common pathway to amputation, preventing ulcerations would have a significant impact on reducing amputation rates and the associated morbidity and mortality.

Foot Ulcer Prevention

Hicks and colleagues showed that the cost of curative care for diabetic foot ulcers is 5-30 times greater than cost of preventive care[8]. In 2015, the International Working Group on the Diabetic Foot (IWGDF) published a systematic review on ulcer prevention[9]. Using a cumulative theoretical model of the existing evidence available for ulcer prevention, the authors stated that 75-80% reduction in ulcer recurrence is

possible. This model of prevention includes integrated foot care, comprehensive diabetic foot education, therapeutic footwear, and patient self-management temperature monitoring.

Integrated Foot Care: Multidisciplinary Management, Podiatry and Nursing

Through the decades, the multidisciplinary approach to management of wound care patients, who often have multiple co-morbidities, has become standard. Previous studies have demonstrated a reduction of major amputations by up to 80% simply in centers that function as a multidisciplinary group[10]. The success of these centers of excellence likely revolves around use of mid-level providers and care coordinators, strong focus on surveillance and education, appropriate and timely consultations, and the expedited management of these complicated patients.

The benefit and value of podiatry as part of the multidisciplinary team in management of the diabetic foot has been previously reported[11]. The field of podiatry has emerged as a group on the front-line for management of DFUs and more importantly, focused on prevention of lower extremity complications associated with diabetes. Gibson and colleagues published data from over 32,000 records reviewed as part of a Thomson Reuter's marketplace research base demonstrating the significant impact of podiatrists on lower extremity complication prevention[12]. The data revealed that care by a podiatric physician, as defined as one preventive pre-ulcer visit, was associated with a 29% lower risk of amputation and a 24% lower risk of hospitalization. The research further showed that for every dollar invested in care by a podiatrist, there was a resultant $27 to $51 of healthcare savings. In contrast, the opposite effect was seen in an analysis by Skrepnik and colleagues of a convenient natural experiment: cancellation of podiatrist reimbursement for Arizona Medicaid beneficiaries in 2009[13]. After controlling for beneficiary characteristics before and after the reimbursement change, they found that for every $1 saved on eliminated podiatry visits, there was a commensurate $48 increase in hospitalization charges.

The value of the podiatric visit is the comprehensive lower extremity examination, the opportunity to make shoegear recommendations and referrals, provide detailed foot education, and establish an appropriate routine foot care interval. In certain situations, curative or prophylactic surgery could also be recommended by a foot specialist. Caution must be taken in selecting appropriate surgical patients, as advanced and complicated co-morbidities are common.

A recent study by Schmidt and colleagues also showed the benefit of podiatry as part of the multidisciplinary team[14]. This study directly compared two eras of care at a single major university teaching hospital in the Midwest, one with podiatry presence and one without. It was found that the addition of a podiatry program at the facility resulted in statistically significant increased limb salvage rates and decrease in high-low amputation ratio. The study revealed that approximately 40 major lower extremity amputations were avoided per year at this institution alone simply by having podiatrists as part of the treatment team.

While podiatrists are commonly the front line for providing comprehensive diabetic foot examinations and education, nurses and diabetes educators can also play a significant role in complication prevention, especially in high risk populations such as dialysis patients. Pernat and colleagues published outcomes of nurse-performed, routine monthly foot checks for all diabetic hemodialysis patients in a large US-based hemodialysis network in 2008[15]. Implementation of the monthly foot check program was associated with a significant 17% lower rate of major lower limb amputations, when compared with the pre-implementation period.

Footwear

Bergin and colleagues reported that 54% of ulcerations in a cohort of 472 patients were directly attributed to trauma from footwear[9]. Since inappropriate or ill-fitting shoegear is often associated with foot ulcerations, it seems reasonable that preventative strategies should include shoe and insert

recommendations. Ideal footwear for people with diabetes at risk for ulceration should be designed to relieve pressure, provide shock absorption, minimize shear forces, and be able to accommodate simple foot deformities such as bunions or hammertoes. In limited cases where deformities are more complex, such as Charcot feet or non-conventional amputations, custom shoegear may be necessary. The most important function of shoes in this high risk population is to serve as a protective barrier to the environment. Thus, a simple concept frequently overlooked by patients is that shoes only provide protection when worn. Previous studies by Reiber and colleagues describe frequent patient dissatisfaction with prescribed shoes for a variety of reasons including improper fit, unacceptable appearance, high cost, excessive time between ordering and receiving prescription shoes, limited colors, styles, materials, shoe weight, and durability[16].

Previous studies on adherence with prescribed footwear have mostly been conducted with subjective methodology including patient questionnaires and diaries. Even in these self-reports, it is evident that patients are not wearing prescribed footwear regularly. Previous studies document that only between 22-36% of patients with diabetes and neuropathy, arterial disease, or foot deformity wear their prescription shoes and inserts greater than 80% of the day[17]. More recently, Waaijman and colleagues monitored adherence to prescribed footwear in 107 patients with diabetes, neuropathy, and a recently healed foot ulceration[18]. This group measured custom footwear use over seven consecutive days using a shoe-worn temperature-based sensor. Daily steps were also measured and the patients were asked to keep a diary of time spent away from home. This study demonstrates an enormous opportunity for patient education: patients have the frequent misconception that it is not as important to use their prescribed shoes at home. The authors found that mean adherence of shoe use at home was 61% compared to 87% away from home. The significant time not spent in shoes, especially while at home, places these patients at high risk for recurrent problems[19].

Foot Temperature Monitoring

Monitoring for skin temperature asymmetry can identify patients with elevated risk for ulceration. Various ways of temperature monitoring have been researched including dermal thermometry by self-care, in-clinic cameras, and in-home/remote monitoring. Three randomized, controlled studies have been conducted using dermal thermometry as a tool for detection of inflammation on the plantar foot. In each study, the information from the dermal thermometry readings informed subsequent offloading intervention recommendation, resulting in a reduction of DFU incidence by approximately 70%[20-22]. This data has resulted in temperature monitoring being incorporated into several clinical practice guidelines, including the most recent recommendations from the International Working Group on the Diabetic Foot (IWGDF).

Despite evidence and guidance, temperature monitoring is not commonly used by people with diabetes. Several factors may have limited broader adoption of temperature monitoring to date, including poor patient workflow involving manual temperature measurement and assessment, inability to monitor adherence remotely and re-engage when necessary, and lack of communication with the care team and an unrealistic expectation of the patient to manage self-care in response to concerning temperature readings.

Recently, Frykberg and colleagues published on a novel remote foot temperature monitoring system that may address some of these barriers to adoption. They studied a smart mat and found it to be 97% accurate in predicting diabetic foot ulcers with an average lead time of 37 days. This prospective trial of

129 patients was conducted on diabetic patients with history of healed ulceration, or amputation, or presence of neuropathy and deformity placing them at high risk for ulceration. Daily, the patients were instructed to step on a smart mat containing approximately 2,000 temperature sensors and through remote monitoring, temperature asymmetry was evaluated[23]. This updated technology is emerging with potential for significant impact on ulcer prevention.

Limitations of Prevention

It is unrealistic to think that all diabetic foot ulcers can be prevented. Annual incidence of first ulceration in persons with diabetes and neuropathy has been reported at 7.5%[24]. In 2016, the IWGDF published a systematic review on prevention of foot ulceration. They reviewed a total of 30 controlled studies (19 RCTs) and another 44 non-controlled studies. They reported that few controlled studies, of generally low to moderate quality, were identified on the prevention of a first foot ulcer. For the prevention of recurrent plantar foot ulcers, multiple RCTs with low risk of bias show the benefit for the use of daily foot skin temperature measurements and consequent preventative actions, as well as for therapeutic footwear that demonstrates to relieve plantar pressure and that is worn by the patient[25]. It is curious that little research has been conducted on prevention of first foot ulceration among persons with diabetes. Risk factors are well established, but interventions and prevention only seem to appear in the literature for recurrent foot ulcers. Once ulceration has occurred, recurrence rates are extremely high. Upon ulcer healing or after an amputation, none of the patient's risk factors have been eliminated. They still have neuropathy and often, deformity is increased. Recurrence rates for ulcers have been reported at 30-40% in the first year after an ulcer episode[24].

Adherence to the established prevention recommendations by providers and patients will affect outcomes, both for primary and secondary ulcer prevention. The 2015 IWGDF systematic review also looked at patient adherence. As expected, the studies that reported on adherence showed that patients

who are adherent to advice given, undergo professional care, monitor their foot temperatures, or wearing their therapeutic footwear, have significantly better outcomes than those who were non-adherent. This review underscored the five key elements that are related to successful prevention of foot complications including: identification of the at-risk foot, regular professional and daily self-inspection of feet, education of patients, family members, and healthcare providers, routine use of appropriate footwear, and treatment of pre-ulcerative signs including pressure and temperature indicators[25]. To help providers better appreciate strategies available for ulcer prevention, Morey-Vargas and colleagues published on the mnemonic "BE SMART" (Be aware of risk factors, Educate patients and health providers, Structured clinical assessment, Metabolic evaluation and management, Assessment of Risk, and Team care) [26]. Clinicians should explore their own potential biases or limitations for including of all these aspects for management of high risk complicated patients.

Conclusion

The case studies in this paper are examples of two high-risk diabetic foot patients. In the first case, with Charcot arthropathy and history of foot ulcer, appropriate prevention strategies were employed. While this patient still experienced complications, it would be hypothesized that careful vigilance through evidence-based strategized minimized mortality and resulted in a more positive outcome. The second case shows the cascade of costly outcomes, including hospitalization when prevention is not followed, especially as related to offloading.

Future directions to incorporate the paradigm shift towards ulcer prevention include a strong focus on first ulcer prevention and a second tier for prevention of those who have already demonstrated high risk status with a previous ulceration or amputation. Globally, best practices should be shared after interventions and outcomes, including cost-effectiveness, are studied. There are clear knowledge gaps in the literature regarding ulcer prevention, especially as related to non-adherence with recommendations

and first ulcer prevention. There are also practice gaps in well studied strategies such as temperature monitoring. Currently, state-of-the-art for prevention of recurrent ulceration in high risk patient populations include home monitoring of foot temperature, pressure-relieving therapeutic footwear, and extensive education regarding daily self-examinations.

1. Rice JB, Desai U, Cummings AK, Birnbaum HG, Skornicki M, Parsons NB. Burden of diabetic foot ulcers for medicare and private insurers. *Diabetes Care* 2014;37:651-658
2. Armstrong, DG, Boulton, AJM, Bus, SA. Diabetic foot ulcers and their recurrence. *NEJM*, 2017;376:2367-2375
3. Skrepnek, GH, Mills Sr., JL, Lavery, LA, Armstrong, DG. Health Care Service and Outcomes Among an Estimated 6.7 Million Ambulatory Care Diabetic Foot Cases in the U.S. *Diabetes Care*, 2017
4. Waaijman R, de Haart M, Arts ML, et al. Risk factors for plantar foot ulcer recurrence in neuropathic diabetic patients. *Diabetes Care* 2014;37:1697-1705
5. Bus, SA and van Netten, JJ. A shift in priority in diabetic foot care and research: 75% of foot ulcers are preventable. Diabetes Metab Res Rev 2016; 32(Suppl. 1): 195–200
6. Driver VR, Madsen J, Goodman RA: Reducing amputation rates in patients with diabetes at a military medical center: the limb preservation service model. *Diabetes Care* 2005; 28: 248–253.
7. Mayfield JA, Reiber, GE, Maynard, C, Czerniecki, JM, Caps, MT, Sangeorzan, BJ et al. Survival following amputation. Journal of Rehabilitation Research and Development. 2001;38: 341-345
8. Hicks CW, Selvarajah, S, Mathioudakis, N, et al. Trends and determinants of costs associated with the inpatient care of diabetic foot ulcers. Journal of Vascular Surgery 2014;60.5:1247-1254
9. Bakker, K, Apelqvist, J, Lipsky, BA, et al. The 2015 IWGDF guidance documents on prevention and management of foot problems in diabetes: development of an evidence-based global consensus. Diabetes Metab Res Rev 2016; 32(Suppl. 1): 2–6
10. Trautner C, Haastert B, Giani G, Berger M. Incidence of lower limb amputations and diabetes. Diabetes Care. 1996;19:1006–9

11. Sloan F, Feinglos MN, Grossman DS. Receipt of care and reduction of lower extremity amputations in a nationally representative sample of U.S. Elderly. *Health Res Educ Trust* 2010;45 6p1:1740–62
12. Gibson TB, Driver VR, Wrobel JS, et al. Podiatrist care and outcomes for patients with diabetes and foot ulcer. *Int Wound J*, 2014;11:641–648
13. Skrepnik, GH, Mills, JL, Lavery, LA, Armstrong, D. Health Care Service and Outcomes Among an Estimated 6.7 Million Ambulatory Care Diabetic Foot Cases in the U.S. Diabetes Care 2017 May
14. Schmidt BM, Wrobel JS, Munson ME, et al. Podiatry impact on high-low amputation ratio characteristics: A 16-year retrospective study, *Diabetes Research and Clinical Practice* 2017;26: 272-277
15. Pernat A, Peršič V, Usvyat L, et al. Implementation of routine foot check in patients with diabetes on hemodialysis: associations with outcomes. *BMJ Open Diabetes Research and Care* 2016;4:e000158:1-7
16. Bergin SM, Gurr, JM, Allard, BP, et al. Australian Diabetes Foot Network: management of diabetes-related foot ulceration—a clinical update. *Med J of Australia* 2012;197.4:226-229
17. Reiber GE, Smith, DG, Wallace, C, et al. Effect of therapeutic footwear on foot reulceration in patients with diabetes: a randomized controlled trial. *JAMA* 2002;287.19:2552-2558
18. Waaijman R, Keukenkamp, R, de Haart, M, et al. Adherence to wearing prescription custom-made footwear in patients with diabetes at high risk for plantar foot ulceration. *Diabetes Care* 2013;36.6:1613-1618
19. Macfarlane DJ, Jensen JL. Factors in Diabetic Footwear Compliance. *J Am Podiatr Med Assoc*. 2003;93(6):485-491
20. Lavery LA, Higgins KR, Lanctot DR, et al. Home monitoring of foot skin temperatures to prevent ulceration. *Diabetes Care* 2004;27:2642-7

21. Armstrong DG, Holtz-Neiderer K, Wendel C, et al. Skin temperature monitoring reduces the risk for diabetic foot ulceration in high-risk patients. *Am J Med* 2007;120:1042-6
22. Lavery LA, Armstrong DG. Temperature monitoring to assess, predict, and prevent diabetic foot complications. *Curr Diab Rep* 2007;7:416-9
23. Frykberg RG, Gordon, IL, Reyzelman, AM et al. Feasibility and efficacy of a smart mat technology to predict development of diabetic plantar ulcers. *Diabetes Care* 2017: dc162294
24. Abbott CA, Carrington AL, Ashe H, et al. The North-West Diabetes Foot Care Study: incidence of, and risk factors for, new diabetic foot ulceration in a community-based patient cohort. *Diabet Med* 2002; 19:377–384
25. Bus SA, van Netten, JJ, Lavery, LA, et al. IWGDF guidance on the prevention of foot ulcers in at-risk patients with diabetes. *Diabetes Metabolism Research and Reviews* 2016;32.S1:16-24
26. Morey-Vargas OL, Smith, S. BE SMART: Strategies for foot care and prevention of foot complications in patients with diabetes. *Prosthetics and Orthotics International* 2015;39.1:48-60