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Location of plantar ulcerations in diabetic patients referred to a Department of Veterans Affairs podiatry clinic

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Abstract—This study described the location of foot ulcerations via a retrospective chart review of diabetic patients in a Department of Veterans Affairs podiatry clinic and correlated location of ulceration with specific medical parameters. The heel was a site of ulceration in 11% of the patients. By multiple logistic regression, patients with diminished vascular function were more than five times more likely to have heel ulceration than patients with adequate vascular status. The findings suggest that heel ulcerations are more common than originally thought and are associated with diminished vascular status. Further work is necessary for reducing plantar heel pressure in individuals who are not presently candidates for vascular interventions.

Key words: ambulatory status, chart review, diabetes, heel, metatarsal heads, multiple ulcerations, peripheral neuropathy, peripheral vascular disease, plantar ulceration, rehabilitation, retrospective study.

INTRODUCTION

Risk factors for amputations in diabetic patients include (1) deformed and insensate feet, (2) high foot pressures during standing and walking, (3) limited blood flow in feet and calves, and (4) unstable glycemic control [1]. Excessive plantar pressure from diabetic peripheral neuropathy is one of the primary risk factors for foot ulceration in this population [2]. Even in the absence of peripheral vascular disease, patients with peripheral neuropathy showed a seven-fold increase in foot ulceration during a 4-year follow-up period [3], most likely because of poor microcirculation and high plantar pressures that persisted following healing [4].

While much is reported on the overall incidence of ulcerations, little is reported on their specific locations and relative incidence. Most studies focus either on overall number of ulcerations, associated plantar pressures in individuals with foot ulcerations, or general predictors of ulceration (e.g., peripheral neuropathy, foot deformity, and minor trauma) [5]. Frykberg et al. reported that 39 percent of a cross section of individuals with diabetes and peripheral neuropathy had plantar-pressure ulcerations [6]. However, previous studies that addressed specific ulceration location were generally either too small or did not describe ulceration location. Landsman and Sage reported locations on only four patients and three of the four locations were associated with the cuboid joint area [7]. Lavery found that 40 percent of ulcerations were located at the first metatarsal, 40 percent at the second through fifth metatarsals, and 20 percent at the great toe in 25 subjects [8]. However, only these three sites were evaluated. Mueller et al. evaluated 40 patients and

Abbreviations: BMI = body mass index, CI = confidence interval, HbA1c = glycosylated hemoglobin, OR = odds ratio, SD = standard deviation, VA = Department of Veterans Affairs.

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described the location of ulceration in relation to foot deformity [9]. They found that in individuals with an uncompensated varus or valgus forefoot, 88 percent of the ulcerations were at the first or fifth metatarsal. Of the individuals with a compensated varus or valgus forefoot, 50 percent had ulceration at the second, third, or fourth metatarsal head. Mueller et al. concluded that certain foot types are associated with characteristic patterns of ulceration [9]. However, in two large-scale investigations, Apelqvist et al. reported that ulcerations occurred most frequently at the first digit (dorsal and plantar surfaces combined) in 28 percent of a sample of 314 individuals [10] and 29 percent of a sample of 1,073 individuals [11].

However, given that ulceration location is associated with high plantar-pressure locations, it is striking that the incidence of heel ulceration is rarely reported. Reiber et al. [5] reported that the incidence of heel ulcerations was between 3.5 [12] and 14.3 percent [5] depending on the population studied, although the demographics of individuals who had heel versus forefoot ulcerations were not analyzed. Apelqvist et al. reported that the incidence of heel ulceration was 13 percent in a population of 314 individuals [10]. Consequently, the purposes of this study were to (1) describe the location of ulcerations throughout the foot via a retrospective chart review of diabetic patients in a Department of Veterans Affairs (VA) podiatry clinic, and (2) correlate location with specific medical parameters associated with diabetes, vascular, or nutritional status. We hypothesized that the plantar surface of the heel rarely experiences pressure ulceration in individuals with diabetes but heel ulcerations are directly correlated with peripheral neuropathy and impaired vascular status.

METHODS

Procedure

We conducted a retrospective chart review of existing data from calendar year 2001 of patients seen in a VA Greater Los Angeles Healthcare System podiatry clinic. This study was approved by the VA Greater Los Angeles Healthcare System Institutional Review Board. The study podiatrist reviewed each participant's podiatry clinic charts and laboratory records from the time closest to the first appointment for a new ulceration. Patient inclusion criteria for analysis were diabetes diagnosis for more than 5 years and attendance at the podiatry clinic for a new ulceration on the plantar surface of the foot. Charts from patients who did not meet these inclusion criteria were not reviewed further; this included any charts that did not specifically identify the ulceration as on the plantar surface of the foot.

The following predictor variables were collected for all subjects: (1) vascular status via dorsalis pedis pulse palpation, (2) history of amputation, (3) body mass index (BMI) (kilograms/square meter), (4) age, (5) race/ethnicity (Caucasian, African American, Hispanic, and Asian), (6) duration of diabetes, (7) glycosylated hemoglobin (HbA1c) level, (8) sensation via 10 g monofilament testing, (9) ambulatory status, and (10) albumin level.

The outcome variable was location of ulceration and was denoted by the following plantar surface aspects of the foot: (1) first metatarsal head, (2) second metatarsal head, (3) third metatarsal head, (4) fourth metatarsal head, (5) fifth metatarsal head, (6) first digit, (7) second digit, (8) third digit, (9) fourth digit, (10) fifth digit, (11) heel, (12) lateral border of the foot, and (13) medial border of the foot.

Statistical Analysis

Subjects were separated into two groups (i.e., subjects with heel ulceration and subjects without heel ulceration) to estimate the risk of heel ulceration. Data on the prevalence of heel ulceration and the demographic and individual medical characteristics were compared between these two subject groups. We used contingency tables and univariate logistic regression with Pearson's chi-square and Fisher's exact tests (as necessary) to determine statistical significance and associated risk estimates. For determination of statistical significance in the univariate analysis, variation within the dependent variable for interval-level characteristics was compared with independent sample *t*-tests. Multivariate logistic regression was used for estimation of risk (odds ratio [OR]) of heel ulceration. Variables were considered for inclusion in the multivariate model if they were significant in univariate analyses or considered potential confounders. Analyses were performed with the Statistical Package for the Social Sciences for Windows version 11.0 (SPSS, Inc, Chicago, Illinois) The significance level used in this study was $p < 0.05$.

RESULTS

A total of 181 separate ulcerations were recorded from the 117 subject charts. At the time of diagnosis, 40 subjects (34%) from both groups combined had multiple ulcerations. Nearly all subjects were men (99%) and more than half were Caucasian (57%). While 61 percent of the subjects were ambulatory, 10 percent used wheelchairs as their primary mode of ambulation. The mean age for the total sample was 63.5 years (standard deviation [SD] = 10 years). More than one-third of the sample had either diminished (21%) or insufficient (12%) neuropathy function. Additionally, 46 percent of the subjects had inadequate vascular function that was either diminished (17%) or insufficient (29%). **Table 1** provides specific information for each subject group.

Table 1.
Demographic and individual characteristics of data sample (N = 117 patients). Data presented as either mean ± standard deviation or frequency (% of group).

Characteristic	Heel Ulcer (n = 20)	Nonheel Ulcer (n = 97)
Age (yr)	64.8 ± 11.2	63.3 ± 9.7
Male	19 (95)	97 (100)
Race/Ethnicity		
Caucasian	9 (45)	58 (60)
African American	9 (45)	29 (30)
Hispanic	1 (5)	9 (9)
Asian	1 (5)	1 (1)
Body Mass Index (kg/m^2)	26.1 ± 7.3	29.7 ± 5.5
Amputation	3 (15)	32 (33)
Ambulation		
Ambulatory	13 (65)	59 (61)
Prosthetic	2 (10)	31 (32)
Wheelchair	5 (25)	7 (7)
HbA1c	7.5 ± 1.9	8.0 ± 2.2
Sensation*		
Adequate	11 (65)	63 (65)
Diminished	3 (18)	22 (23)
Insufficient	3 (18)	11 (12)
Vascular Status*†		
Adequate (Able to Palpate)	5 (26)	56 (58)
Diminished (Barely Palpable)	8 (42)	12 (13)
Insufficient (Unable to Palpate)	6 (32)	28 (29)
Multiple Ulcerations	2 (10)	—

*Totals do not equal n for group because of missing data.
†Vascular status was determined by palpation of dorsalis pedis and classification of findings was based on a clinical scale.
HbA1c = glycosylated hemoglobin.

The prevalence of heel ulceration was 17 percent (n = 20), which accounted for 11 percent of all foot ulcerations (n = 181) (**Table 2**). We also compared subjects with multiple ulcerations and subjects with a single ulceration, differentiated by location (heel vs nonheel), using chi-square analysis. Of the subjects with heel ulceration, 85 percent had a single ulceration, compared with only 62 percent of the subjects with nonheel ulceration, and exhibited significantly lower frequency of multiple ulcerations (χ^2_1 = 3.95, p = 0.047). The corresponding OR demonstrated that subjects who did not have heel ulceration were more than three times more likely to have multiple ulcerations.

Differences between the heel and nonheel ulceration groups for interval-level data (age, HbA1c, albumin, and BMI) were not significant by t-tests except for BMI. Mean BMI was significantly higher in subjects with nonheel ulceration than subjects with heel ulceration (mean ± SD = 29.7 ± 5.5 kg/m^2 vs 26.1 ± 7.3 kg/m^2, respectively, $t_{(113)}$ = 2.54, p = 0.016).

We also used chi-square analysis to examine nominal- and ordinal-level data (race/ethnicity, amputation, ambulation, neuropathy, and vascular function). Simple cross-tabulations indicate that race, amputation, and neuropathy level were not correlated with heel ulceration (p > 0.05).

Table 2.
Frequency of ulceration locations expressed as absolute number and percent of total number of ulcerations (N = 181).

Location	Absolute No. (%)
Metatarsal Heads	
Combined	102 (53.6)
1st	30 (16.6)
2nd	20 (11.0)
3rd	15 (8.3)
4th	12 (6.6)
5th	25 (13.8)
Digits	
Combined	52 (28.8)
1st	34 (18.8)
2nd	11 (6.1)
3rd	4 (2.2)
4th	1 (0.6)
5th	2 (1.1)
Heel	20 (11.0)
Lateral Border of Foot	4 (2.2)
Medial Border of Foot	3 (1.7)

However, the two groups significantly differed by ambulation status ($\chi^2 = 8.18$, $p = 0.02$) and vascular function level ($\chi^2 = 11.36$, $p = 0.003$). Univariate analysis with logistic regression revealed a trend toward statistical significance for subjects with heel ulceration who used a wheelchair relative to subjects with heel ulceration who were ambulatory ($p = 0.059$). This trend was significant when wheelchair use was compared with prosthetic use (OR = 11.07, 95% confidence interval [CI] = 1.77 to 69.26, **Table 3**). Subjects with diminished vascular function were more than seven times more likely to have a heel ulceration when compared with their counterparts with adequate vascular function (OR = 7.33, 95% CI = 2.04 to 26.38, **Table 3**).

Analysis by multiple logistic regression was also used for testing the association of risk factors for heel ulceration. The analysis revealed that after we adjusted for age, BMI, HbA1c, albumin, and ambulatory status, the presence of a heel ulceration increased more than five-fold for subjects with diminished vascular function (OR = 5.7, 95% CI = 1.07 to 30.44, $p = 0.042$, **Table 4**). None of the other demographic or individual characteristics was significantly related to the risk of heel ulceration presence (**Table 4**).

DISCUSSION

While previous studies have primarily focused on incidence of forefoot ulceration, this study demonstrated that 11 percent of the ulcerations observed in a podiatry clinic occur at the heel, which is similar to findings by Apelqvist et al. (13%) [10] and Reiber et al. (3.5%–14.3%) [5]. More important than the incidence, however, is that heel ulcerations appear to be related to diminished vascular function.

Table 3.
Univariate analysis of factors associated with heel ulceration.

Factor	Odds Ratio	95% CI	*p*-Value
Ambulation			
Prosthetic vs Ambulatory	0.32	0.07–1.51	0.149
Wheelchair vs Ambulatory	3.51	0.95–12.95	0.059
Wheelchair vs Prosthetic	11.07	1.77–69.26	0.010
Vascular Function			
Diminished vs Adequate	7.33	2.04–26.38	0.002
Insufficient vs Adequate	1.90	0.51–7.09	0.341

CI = confidence interval.

Table 4.
Independent associations with heel ulceration.

Factor	Odds Ratio	95% CI	*p*-Value
Age (yr)	0.97	0.91–1.03	0.296
Body Mass Index	0.89	0.77–1.02	0.084
HbA1c	0.96	0.71–1.30	0.778
Albumin	2.01	0.53–7.59	0.305
Ambulation*			
Prosthetic	0.35	0.06–1.88	0.218
Wheelchair	5.07	0.85–30.42	0.076
Vascular Function†			
Diminished	5.70	1.07–30.44	0.042
Insufficient	1.61	0.38–6.91	0.519

*Reference group was patients considered to have "adequate" ambulation.
†Reference group was patients considered to have "adequate" vascular function.
CI = confidence interval, HbA1c = glycosylated hemoglobin.

In our study, we observed that subjects with diminished vascular status were more than five times more likely to have an ulceration on the heel than subjects with adequate vascular function, although subjects with insufficient vascular function did not demonstrate significant differences. Reiber et al., however, found that lower-limb ischemia was a component cause in only 35 percent of causal pathways and not a significant cause of foot ulceration in any subject [5]. Clinically, early interventions and vascular precautions (e.g., referral to the vascular surgery department) are initiated for individuals whose ankle and pedal pulses are palpable (a measure of insufficient vascular status). These precautions, however, are not generally initiated for individuals whose ankle and pedal pulses are barely palpable (a measure of diminished vascular status). We suggest that in individuals with diabetic peripheral neuropathy and diminished vascular status, the high heel-pressure levels commonly observed [13] may result in a selective ulceration of the heel. Possibly, the techniques commonly used for the prevention of forefoot ulcerations, such as special shoes, may prevent heel ulcerations if redesigned to focus on heel-pressure reduction.

While Reiber et al. found that peripheral neuropathy was a strong component in the causal pathway to foot ulceration [5], our study showed no difference between subjects who did and did not have heel ulceration in relationship to peripheral neuropathy. Unexpectedly, we observed that subjects who had heel ulceration were more likely to use wheelchairs as their primary mode of ambulation (although wheelchairs were not their only

mode of ambulation). While this may be the result of the location of weight-bearing (the plantar surface of the foot is in contact with the footplate at all times while using the wheelchair), one should note that the majority (65%) of subjects with heel ulceration were ambulatory. Given the retrospective nature of this study, we were unable to measure the subjects' activity levels, although all subjects whose charts were reviewed were outpatients. Recent studies have evaluated activity levels in relationship to ulceration. Lemaster et al. studied weight-bearing activity in 400 subjects with diabetes and previous history of ulceration [14]. The subjects who were "least active" (less than 4.5 hours a day of weight-bearing activity) were at most risk for reulceration. The subjects who were "most active" (greater than 7.5 hours a day of weight-bearing activity) had significantly reduced risk of reulceration. Armstrong et al. found that activity levels were significantly lower in subjects who ulcerated relative to subjects who did not [15]. All subjects in that study had diabetic peripheral neuropathy but may or may not have had previous ulcerations and all ulcerations during the study period were on the forefoot. Regardless of ulceration history, the subjects who did not ulcerate during the study period were more active.

CONCLUSIONS

Most studies focus on whether a person ulcerates or not. In this case, neuropathy status and plantar pressure are critically important to the prediction of ulceration likelihood. When location is evaluated, other factors appear to be important, such as vascular and ambulation status. The importance of understanding the risk factors for heel ulcerations stems from the lack of available treatments for heel ulcerations. Additionally, heel ulcerations occur in more than 10 percent of individuals and this group may be more severely compromised in terms of vascular status [11]. Given the cost of ulceration treatment [16], clinicians must recognize the potential for heel ulcerations, especially in patients with diminished vascular status. Further research needs to focus on the effectiveness of interventions for patients with diminished vascular status. These interventions may include earlier initiation of interventions that are currently reserved for patients with absent pulses, such as vascular precaution-bed cradles, heel protectors, exercise tolerance education, more frequent clinic visits, possible oral therapeutic agents, and vascular surgery consults.

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