Risk Factors for Recurrent Diabetic Foot Ulcers

Site matters

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The rate of recurrent ulceration in diabetic patients with a history of foot complications is high (1–6). The purpose of this study was to evaluate the outcome of diabetic foot ulcers and to study the risk factors for recurrent foot ulcers in a high-risk setting such as a specialized tertiary diabetic foot center.

RESEARCH DESIGN AND METHODS — The study was set up as a prospective cohort study to evaluate risk factors for secondary diabetic foot ulcers. At enrollment, 81 subjects presented with an ulcer distal to the ankle and were sequentially enrolled from a high-risk foot clinic at an urban teaching institution. Patients without follow-up visit at the diabetic foot clinic were excluded from the study. All patients were assessed at the foot clinic at intervals necessary for either treatment or for regular care according to international standards (7). Part of the data of this cohort of patients has been previously published (8). Tactile, vibratory nerve function, three-step mean plantar pressure, range of motion, and multiple vascular parameters were assessed using previously described techniques (1,9–11). Plantar peak pressures >70 N/cm^2 were defined as elevated (1,3,8,12–15).

The presence of risk factors in the group of patients that developed an ulcer in the follow-up period was compared with the presence of these factors in the group of patients without a follow-up ulcer. Secondary points were incidence of amputation, recurrent ulcers, the amputation level, reamputations, and necessity for peripheral arterial bypass. A reulceration was defined as an ulcer at the same location as a previous one. A recurrent ulcer was defined as any secondary ulcer regardless of its location. For purposes of analysis, the foot was divided into four different regions.

RESULTS — Of the initially presenting ulcers, 71.6% healed, 12.3% were not healed at the end of the follow-up period, and 16.0% had led to a lower-extremity amputation. The median duration of follow-up was 31.5 months ([mean ± SD] 27.1 ± 9.2).

Of the total population, 60.5% of the patients developed an ulcer in the follow-up period. The incidence of ulceration was 26.8 per 100 patients per year. If multiple ulcers were counted as separate events, the incidence rose to 56.3 per 100 per year. Of 24 patients with a plantar first-ray ulcer, 7.7% (2 of 24) required an amputation during the follow-up period compared with 20% (11 of 44) of patients with an ulcer at a different location ($P > 0.05$). Plantar peak pressures for patients with a first-ray ulcer were 86.0 ± 22.0 vs. 84.2 ± 25.0 N/cm^2 ($P > 0.05$) for patients with any other ulceration at enrollment. A total of 14.3% of patients with an ulcer in the follow-up period received a peripheral artery bypass, compared with none of the patients without a follow-up ulcer (odds ratio 1.17 [95% CI 1.04–1.31]; $P = 0.025$). Eight reamputations were performed in the follow-up period.

The majority of the ulcers at the lesser toes occurred on the dorsal aspect (91%, $n = 32$). All of the ulcers at the great toe were plantar. Compared with all other groups combined, patients with plantar hallux ulcers developed significantly more ulcers in the follow-up period (83.3% [$n = 18$] vs. 54.0% [$n = 63$]; $P = 0.025$; odds ratio 4.3 [95% CI 4.1–4.5]). Compared with other groups, ulcers at the lesser toes were least likely to heal during the period of follow-up (65.6% [$n = 32$] vs. 77.1% [$n = 49$]; $P = 0.24$; 1.6 [1.6–1.7]), and a large percentage of lesser toe ulcers ended with an amputation (25.0% [$n = 32$] vs. 10.2% [$n = 49$]; $P = 0.073$; 2.9 [2.8–3.1]).

Patients with a plantar hallux ulceration were most likely to get another ulceration at the same location (reulceration) as the index ulcer compared with the other groups (50.0% [$n = 18$] vs. 14.3% [$n = 63$]; $P = 0.002$; odds ratio 6.0 [95% CI 5.8–6.2]). In further analysis, patients were grouped in either a group of patients with a plantar hallux or submetatarsal ulcer (both plantar forefoot ulcers) or a group of patients with ulcers at another location. Reulceration at the same location was more likely in the group of patients with a plantar hallux or submetatarsal ulcer at enrollment compared with ulcers at any other location (43.2% [$n = 37$] vs. 4.5% [$n = 44$]; $P = 0.002$; 9.1 [8.6–9.5]). History of amputation, history of first-ray amputation, or presence of hallux rigidus was not significantly more prevalent in patients with a recurrent ulceration.

Risk factors for recurrent ulceration in a univariate analysis are shown in Table 1. Risk factors with $P < 0.20$ from the univariate analyses were taken to construct a logistic regression model. Location of ulceration was also included in this model. Significant risk factors from the logistic regression analysis were periph-

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A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

Table 1—*Univariate and subsequent multivariate analysis of risk factors for an ulcer in the follow-up period*

	Follow-up ulcer	No follow-up ulcer	*P* value	Odds ratio (95% CI)	Coefficient (logistic regression)	Estimated odds ratio (logistic regression)
n	49	32				
Male sex	73.5	81.3	>0.3			
Age >60 years	20.4	34.4	0.161	0.5 (0.2–1,3)		
Age (years)	52.6	53.	>0.3			
Type 2 diabetes	95.9	93.8	>0.3			
Duration of diabetes >10 years	73.5	56.3	0.11	0.2 (0.1–1.6)		
Alcohol abuse past and present	46.9	50.0	>0.3			
Tobacco abuse past and present	55.1	65.6	>0.3			
Nephropathy (at least microalbuminuria)	56.3	50.0	>0.3			
Retinopathy (at least background changes)	86.1	79.2	>0.3			
History of amputation	40.8	34.3	>0.3			
A1C >9%	70.5	66.7	>0.3			
Plantar peak pressure >70 N/cm^2	60.0	55.2	>0.3			
Peak pressure forefoot (N/cm^2)	85.7	83.7	>0.3			
$TcpO_2$ <30 mmHg	41.9	25.0	0.15	0.2 (0.1–1.5)		
$TcpO_2$ (mmHg)	38.8	42.3	>0.3			
Neuropathy (SWM missing or vibratory perception threshold >25 V)	91.7	90.6	>0.3			
Vibratory perception threshold (V)	39.1	34.9	0.11			
Peripheral vascular disease (any pedal pulse missing or ankle-brachial index <0.8)	42.9	9.4	<0.001	0.3 (0.1–3.2)		
Ankle-brachial index	0.93	1.10	>0.3			
Rigid toe deformity or charcot deformity	87.8	81.3	>0.3			
Hallux rigidus	28.6	15.6	0.18	0.1 (0.1–1.3)		
Pes equinus	36.7	28.1	>0.3			
Any rigid deformity	73.5	65.6	>0.3			
BMI (kg/m^2)	29.8	29.8	>0.3			
Cholesterol (mg/dl)	196	182	0.21			
Smoking: pack-year history (years)	17.4	15.8	>0.3			
Years of education	11.2	9.1	>0.3			
Peripheral vascular disease (multivariate)			0.006		2.3	10.1
Location of index ulcer at plantar hallux (multivariate)			0.038		1.7	5.3

Data are percent, unless otherwise indicated. The factors for foot ulceration after a previous ulceration entered into the logistic regression analysis model were age >60 years, duration of diabetes >10 years, peripheral vascular disease (any missing pulse or ankle-brachial index <0.8), presence of hallux rigidus, and location of index. Variables with $P < 0.2$ in the logistic regression analysis are displayed in the bottom two lines of the table. The χ^2 of the Hosmer and Lemeshow goodness-of-fit test was 3.8 with $P = 0.81$, indicating that the model was well calibrated and that the data fit well. SWM, any missing sensation with the Semmes-Weinstein monofilament 10 g; $TcpO_2$, transcutaneous partial oxygen pressure.

eral vascular disease ($P = 0.006$, estimated odds ratio 10.1) and location of the index ulcer at the plantar aspect of a toe ($P = 0.038$, estimated odds ratio 5.3).

CONCLUSIONS — Risk factors that were identified in our study were peripheral vascular disease and location of index ulcer. It is uncertain whether these risk factors play an etiological role in the development of an ulcer. In this perspective, it might be better to speak of indicators for potential recurrent ulceration instead of risk factors. The methods and definitions were based on previous publications and the recommendations of the International Working Group on the Diabetic Foot (7). Only a few reports are available on the risk of new ulcers after an ulcer has occurred (16–19). Although many had relatively long follow-ups, the studies were either retrospective in nature or did not include robust multivariate analyses, with none specifically evaluating location as a factor.

Patients with plantar hallux ulcers were significantly more likely to develop additional ulcers. Ulcers on the bottom of the foot are generally believed to be due to repetitive injury to an insensitive foot (20). In contrast with ulcers on the great toe, most of the ulcers on the lesser toes were on the dorsum. These dorsal wounds are usually the result of ill-fitting shoes. Once this mechanism of injury is identified, simply providing shoes that have an adequate toe box is probably a sufficient remedy to avoid reinjury. This simple prevention measure is probably more effective to reduce reulceration.

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