

# What are the most effective interventions in preventing diabetic foot ulcers?

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## ABSTRACT

Although many studies have shown strong associations between certain causal factors and patients with foot ulcers, it is unclear how many of these factors interact. A model that could help identify unique causal pathways and pivotal factors associated with the development of foot ulcers may lead to earlier intervention as well as less frequent and less severe complications. Therefore, the purpose of this study was to identify the responsible causal pathways associated with foot ulcers in persons with diabetes, to determine the frequency of components of the pathway and to identify pivotal events of the pathway. Eighty-seven patients with 103 existing or recently healed ulcers were prospectively evaluated. The data used in the pathway analysis reflected seven variables that have been associated with the development of foot ulcers. The data were interpreted to assess which component causes and pivotal events were responsible for the present ulcer. A cluster analysis was used to confirm findings from the descriptive analysis. Twenty-four pathways were identified. The seven most common unique pathways accounted for 64.1% of the cases. The results of the cluster analysis showed four consistent, dominant clusters: (i) neuropathy, deformity, callus and elevated peak pressure; (ii) peripheral vascular disease; (iii) penetrating trauma and (iv) ill-fitting shoe gear. These results suggest that there is a finite number of key factors that, if identified and addressed with appropriate intervention strategies, may reduce the risk for the cascade of events towards ulceration and subsequent amputation.

**Key words:** Diabetes • Feet • Inflammation • Prevention amputation • Thermometry • Ulcer • Wound

## INTRODUCTION

Diabetes continues to be the single most common disease associated with lower extremity amputations in the USA (1,2). Amputations have been associated with an increased risk of recurrent ulceration (3,4), additional amputations of the ipsilateral and contralateral leg (5) and a high incidence of perioperative (6,7) and postoperative mortality (8). In addition, for as many as a quarter of amputees, an amputation is a pivotal event that leads to nursing home

placement and a marked deterioration of their quality of life (9). At least 85% of lower extremity amputations is preceded by a diabetic foot ulcer (10).

Despite information that shows that a multidisciplinary approach to treatment and prevention is capable of reducing the recurrence of ulceration and the incidence of lower extremity amputations (11,12), widespread implementation of this type of approach has not been fully realised. The goal of Healthy People 2000/2010 and the St Vincent's Declaration was to reduce the incidence of diabetes-related amputation by up to 50% (13–15). Recent reports suggest that the incidence of amputation has not significantly changed and, in some regions, may have increased (1,16,17). This may be because of the fact that, in many medical facilities, a systematic foot screening to identify patients at high risk for amputation is simply

## Key Points

- amputations have been associated with an increased risk of recurrent ulceration additional amputations of the ipsilateral and contralateral leg and a high incidence of perioperative and postoperative mortality
- at least 85% of lower extremity amputations is preceded by a diabetic foot ulcer
- despite information that shows that a multidisciplinary approach to treatment and prevention is capable of reducing the recurrence of ulceration and the incidence of lower extremity amputations, widespread implementation of this type of approach has not been fully realised
- recent reports suggest that the incidence of amputation has not significantly changed and, in some regions, may have increased
- in many medical facilities, a systematic foot screening to identify patients at high risk for amputation is simply not performed on an outpatient or inpatient basis and subsequently, intervention strategies are not appropriately implemented

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**Key Points**

- the purpose of this study was to identify the causal pathways associated with diabetic foot ulcers, to determine the frequency of components of the pathway and to identify pivotal events of the pathway
- eighty seven patients with 103 existing or recently healed ulcers were prospectively evaluated

not performed on an outpatient (18) and inpatient (19) basis. Subsequently, intervention strategies are not appropriately implemented.

There are several systemic and local risk factors that have been associated with the development of foot ulcerations such as visual impairment, retinopathy, poor glucose control, nephropathy, sensory neuropathy, limited joint mobility and peripheral vascular disease (4,20–29). However, simply understanding the risk factors may not be enough to help clinicians identify opportunities to interrupt the disease process. A model that could help identify unique causal pathways and pivotal factors associated with the development of foot ulcers may lead to earlier intervention as well as less frequent and less severe complications. Therefore, the purpose of this study was to identify the causal pathways associated with diabetic foot ulcers, to determine the frequency of components of the pathway and to identify pivotal events of the pathway.

**SUBJECTS AND METHODS**

This project was conducted as part of a case-control study. Eighty-seven patients with 103 existing or recently healed (<4 weeks) ulcers

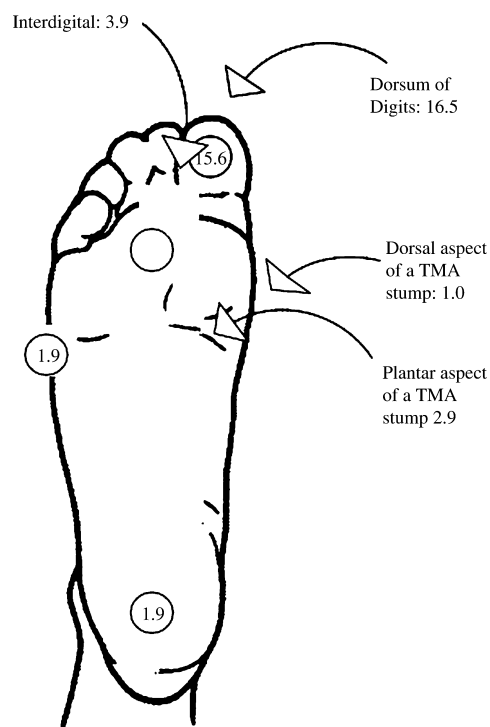
were prospectively evaluated. Diabetic foot ulcers were defined as partial or full-thickness skin loss distal to the malleoli. In several subjects, it was necessary to delay completion of data collection such as foot pressure measurements and vascular testing until patients were able to be scheduled for these procedures or based on the attending physician's wishes, until the ulcer had completely epithelialised. Subjects with bilateral ulcers were regarded as two separate cases for the purpose of pathway analysis because divergent pathways can influence the development of foot ulcers in the same individual. In addition, patients with ulcers on the ankle or leg or patients who were unable to be fully evaluated were eliminated from the study. Following informed consent, all subjects were enrolled sequentially from these clinics. The presence of diabetes mellitus was based on World Health Organization criteria (20), and diabetes was stratified into type 1 or 2, based on the algorithm described by Mogensen (21). Descriptive statistics for this population are summarised in Table 1. Ulcer location is illustrated in Figure 1.

Study participants underwent a physical examination and were interviewed to evaluate

**Table 1** Characteristics of 87 patients with 103 lower extremity ulcers

General demographics	
Age (years)	52.9 ± 10.3 (28–75)
Duration of diabetes (years)	14.7 ± 8.9 (0–43)
% Male	73.6
% Diabetes type 1:type 2	4.6:95.4
General physical examination	
Glycosylated haemoglobin (HbA1c, %)	9.8 ± 2.3 (5.0–17.4)
Body mass index (Quetelet Index, kg/m <sup>2</sup> )	29.9 ± 5.2 (21.2–8.9)
% Nephropathy (at least microalbuminuria)	66.7
% Retinopathy (at least background changes)	65.5
Lower extremity history	
% Lower extremity bypass surgery	4.6
% Amputation at ipsilateral side	31.1
Toe or ray	21.4
Midfoot	9.7
% Amputation at contralateral side	21.3
Toe or ray	13.6
Midfoot	5.8
Below the knee	1.9
Lower extremity physical examination	
% Unable to inspect the sole of the foot	48.3
Vibratory perception threshold (V)	40.0 ± 12.2 (6–50)
Transcutaneous oxygen pressure (mmHg)	44.0 ± 17.9 (10–88)
Ankle brachial index	0.95 ± 0.20 (0.33–0.19)

All data are mean ± standard deviation (range) or percentage of total population.



**Figure 1.** Location of diabetic foot ulcers. Ulcers were located under the metatarsal heads (56.3%), at the dorsal aspect of the toes (16.5%), at the plantar aspect of the toes (15.6%), between the toes (3.9%), at the plantar aspect of a transmetatarsal amputation stump (2.9%), at the heel (1.9%), at the lateral or medial aspect of the foot (1.9%) and at the dorsal aspect of a transmetatarsal amputation stump (1.0%).

exposure variables including demographic data, general medical, surgical, and social history, diabetes and diabetes-related complication history, visual acuity and lower extremity vascular, neurological, musculoskeletal and dynamic foot pressure assessment. We also asked subjects to attempt to place their foot in a position that would allow them to see the bottom of their foot regardless of their visual acuity. For this examination, self-evaluation skill was considered impaired if the subject was unable to position their foot and successfully read 0.5-cm type (22).

We evaluated seven variables that have been previously associated with the development of foot ulcers. These variables were neuropathy, callus, deformity, elevated peak pressure, vascular disease, ill-fitting footwear and penetrating trauma. We assessed peripheral sensory neuropathy using vibration perception threshold testing at the distal great toe using a Biothesiometer (Biomedical Instrument Com-

pany, Newbury, Ohio) (23). Impaired sensation, or loss of protective sensation, was defined as a vibratory perception threshold greater than 25 V (24). Lower extremity peripheral vascular disease was evaluated using two dichotomous variables. These included transcutaneous oxygen tension on the dorsal aspect of the first intermetatarsal space ( $<30$  mm/Hg) (25) and ankle brachial systolic blood pressure index ( $<0.80$ ) (26). Impaired vascular supply was then defined as either ankle brachial index  $<0.8$  or transcutaneous oxygen tension  $<30$  mmHg.

Three measurements of the first metatarsophalangeal joint were averaged to assess limited joint mobility of the forefoot. From these measurements, we determined the presence of hallux rigidus ( $<50$  degrees hallux dorsiflexion) (27–29). To categorise forefoot deformities in addition to hallux rigidus, we evaluated the foot for the presence of hallux valgus, rigid toe contractures (hammer toe, claw toe or mallet toe deformities), subluxation or dislocation of the metatarsophalangeal joints and prominent metatarsal heads on the sole of the foot (27). Limited joint mobility of the forefoot was considered tantamount to deformity. Callus was defined as hyperkeratosis surrounding the ulcer site at the time of presentation or as described in clinic progress notes prior to the development of the ulcer. Additionally, we used the EMED-SF pressure platform system (Novel, Munich, Germany) to evaluate dynamic barefoot pressures on the sole of the foot. An average of pressures from three steps was used for purposes of analysis.

In order to model factors that contribute to the development of a foot ulcer, we constructed a model of causation as described by Rothman (30). Other authors have used this approach to evaluate causal pathways for diabetic lower extremity amputation and to compare causal pathways for ulceration in the USA and UK (10,31). This type of modelling uses a set of minimal conditions that inevitably produce a disease outcome, in this case a foot ulcer. Rothman has defined a cause as an event 'which initiates or permits, alone or in conjunction with other causes, a sequence of events resulting in the effect'. A sufficient cause involves an event that will inevitably produce the disease outcome, while component causes are unable to produce the disease outcome by themselves. A series of component

### Key Points

- we evaluated seven variables that have been previously associated with the development of foot ulcers. These variables were neuropathy, callus, deformity, elevated peak pressure, vascular disease, ill-fitting footwear and penetrating trauma

**Key Points**

- a total of 24 unique pathways were identified from the seven component causes

factors is often required to produce a sufficient cause. This conceptual framework suggests that eliminating or modifying component factors in the disease pathway may render the entire pathway or remaining factors ineffective.

Three researchers individually reviewed the patients' ulcer information and individually interpreted the data to determine which component causes and pivotal events were responsible for the present ulcer. If no consensus was achieved, each pathway was openly discussed until a consensus was reached.

A cluster analysis was performed to confirm findings from the descriptive analysis. A cluster analysis can be used to identify homogeneous groups or clusters (32–34). It is the same method as numerical taxonomy, the method used in biology to classify animals and plants. In this case, a hierarchical binary Lance and Williams non metric method was used. This method is useful if binary values are compared that do not necessarily have a parametric distribution (34). Cluster membership was measured using centroid clustering. This method calculates the distance between two clusters as the distance between their means for all of the variables. In other words, it calculates the proximity of each variable to the others. Next, closely associated variables can be fitted into in agglomerations, homogenous groups. Both of these calculations, those of the separate variables and those of the agglomerations, have values between 0 and 1, 0 implying

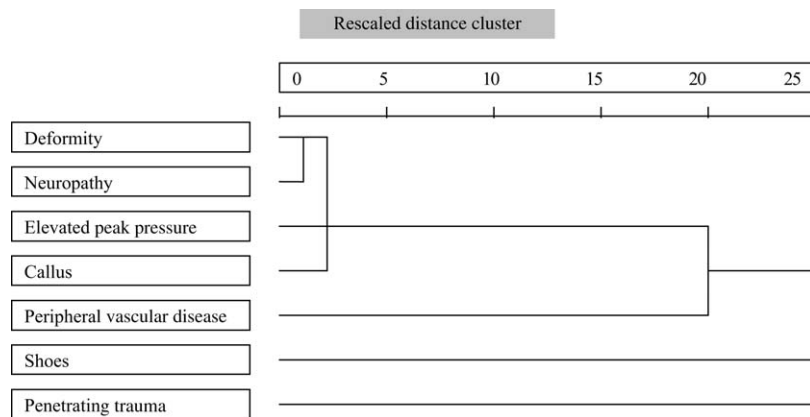
a close relationship and 1 suggesting no relationship at all.

Subsequently, a multidimensional scaling model was used to come to a derived stimulus configuration, again using the binary Lance and Williams method (Figure 2) (35). The distance model is a multidimensional generalisation of the two-dimensional Pythagorean theorem,  $a^2 + b^2 = c^2$ , where the values of the dimensions represent relative distances of the variables to one another. The Lance and Williams method computes the data from a fourfold table as  $(b + c)/(2a + b + c)$ , where  $a$  represents the cell corresponding to cases present on both items and  $b$  and  $c$  represent the diagonal cells corresponding to cases present on one item but absent on the other. This measure has a range of 0–1. The resulting is a figure that shows the relative distance of the factors in a multidimensional field.

Furthermore, a dendrogram was made as a visual representation of the steps in a hierarchical clustering solution illustrating combinations of clusters. Connected vertical lines designate joined cases (Figure 2). The dendrogram rescales the calculated coefficients between the seven components to numbers between 0 and 25. In this way, factors that are always related have a value of 0, while hardly related factors have a connecting value of 25.

**RESULTS**

A total of 24 unique pathways were identified from the seven component causes. The seven



**Figure 2.** Dendrogram of cluster analysis. This displays a dendrogram of the cluster analysis using a hierarchical binary Lance and Williams non metric method with centroid clustering. The dendrogram is a visual representation of the steps in a hierarchical clustering solution that shows the clusters being combined and the values of the distance coefficients at each step. Connected vertical lines designate joined cases. The dendrogram rescales the actual distances to numbers between 0 and 25, preserving the ratio of the distances between steps.

most common unique pathways accounted for 64.1% of the cases. All pathways are illustrated in order of frequency in Table 2.

Neuropathy was the most common pathophysiological condition in the studied group (92.2%). Deformity, callus and elevated peak pressures were relatively common with prevalences of 63.1%, 60.2% and 52.4%, respectively. In all, 23.3% of the ulcers developed in the presence of ischaemia, that is, the patients had either a transcutaneous oxygen level of less than 30 mmHg or an ankle brachial index of less than 0.8; 19.4% of the ulcers were found to be because of ill-fitting footwear, while penetrating trauma was documented in 10.7% of all ulcers.

The cluster analysis indicated the existence of four distinct clusters: (i) penetrating trauma, (ii) ill-fitting footwear, (iii) vascular disease and (iv) neuropathy, deformity, elevated peak pressure and callus. The relative coefficients were 0.634, 0.633, 0.543 and 0.267, respectively. The dendrogram further illustrates that penetrating trauma, ill-fitting shoes and vascular disease are essentially separated from the rest of the factors (Figure 2). These three factors, ill-fitting footwear, penetrating trauma and vascular disease, can therefore be identified as pivotal events.

## CONCLUSIONS

The results of this study suggest that there are four dominant pathways to development of diabetic foot ulcers. These are (i) neuropathy, deformity, callus and elevated peak plantar pressure, (ii) peripheral vascular disease, (iii) penetrating trauma and (iv) ill-fitting shoes. These data appear to be well supported by previous studies that have linked callus (36), elevated pressure (27,37,38), neuropathy (27), deformity (4,27–29,39), vascular impairment (26,27), poor-fitting shoes (40–42) and puncture injuries (43) to the development of foot ulcers in persons with diabetes. Evaluating individual pathways provides a different perspective of the mechanisms of injury and potential intervention strategies to prevent the development of diabetic foot ulcerations compared with risk factors described in previous univariate or multivariate analytic studies. To our knowledge, the only other study that has evaluated causal pathways for diabetic foot ulceration compared pathways from two centres in USA and UK (31). The two

**Table 2** Prevalence of components in causal pathways

Component	% of total population												
Neuropathy	x	x	x	x	x	x	x	x	x	x	x	x	93.1
Deformity	x	x	x	x	x	x	x	x	x	x	x	x	63.1
Callus	x	x	x	x	x	x	x	x	x	x	x	x	60.2
Pressure	x	x	x	x	x	x	x	x	x	x	x	x	52.4
Vascular disease*													23.3
Ill-fitting shoes*													19.4
Puncture injury*													10.7
% of all pathways	20.4	10.7	8.7	7.8	5.8	5.8	4.9	3.9	3.9	3.9	2.9	2.9	1.0

\*Pivotal event.

## Key Points

- the results of this study suggest that there are four dominant pathways to development of diabetic foot ulcers which are: (i) neuropathy, deformity, callus and elevated peak plantar pressure, (ii) peripheral vascular disease, (iii) penetrating trauma and (iv) ill-fitting shoes
- evaluating individual pathways provides a different perspective of the mechanisms of injury and potential intervention strategies to prevent the development of diabetic foot ulcerations compared with risk factors described in previous univariate or multivariate analytic studies

## Key Points

- in centres that focus on screening diabetic patients and implementing prevention strategies, force plate measurements can be performed quickly and help identify patients that may require special protective insoles or shoe modifications. And, while this screening modality is not commonly used today, in future, it could find an important place in risk prevention programmes for diabetic foot complications
- we had expected to identify cases of blunt trauma or burns, but the only cases of trauma identified in our study population involved penetrating injuries
- we had difficulty establishing a workable operational definition to access these variables from either patient history or physical examination, and we therefore did not include this variable in our analysis
- with the advent of computerised step counters, in the future, we should be better able to collect and evaluate objective data to access the role of repetitive trauma from walking as a risk factor and component cause of foot ulcers
- approximately 19% of the ulcers in this study were precipitated by ill-fitting shoe gear
- it was impossible to measure the role of repetitive minor trauma in the development of ulceration
- about 11% of all ulcers were precipitated by a puncture injury
- previous reports have suggested that as many as 41% of puncture injuries in persons with diabetes occur while the patient is not wearing shoes
- the importance of foot puncture injuries as pivotal factors in ulcer development suggest that simple preventative and patient education measures may be very effective in reducing this specific pathway
- the majority of the ulcers evaluated in this study were precipitated by way of a pathway that included neuropathy, deformity, callus and elevated plantar pressure

sites used different techniques to evaluate vascular disease and sensory neuropathy, which may have contributed to inconsistencies in diagnosis across centres. In addition to the variables used in this study, we also included foot pressures on the sole of the foot and penetrating trauma as evaluation criteria. However, we did not include minor trauma and oedema as evaluation criteria as described in Reiber's report. Foot pressure is frequently cited in the literature as an important risk factor for foot pathology (29,37–39,44). In centres that focus on screening diabetic patients and implementing prevention strategies, force plate measurements can be performed quickly and help identify patients that may require special protective insoles or shoe modifications. And, while this screening modality is not commonly used today, in future, it could find an important place in risk prevention programmes for diabetic foot complications.

We had expected to identify cases of blunt trauma or burns, but the only cases of trauma identified in our study population involved penetrating injuries. Reiber and her coworkers identified minor foot trauma and oedema as important factors in their study. We had difficulty establishing a workable operational definition to access these variables from either patient history or physical examination, and we therefore did not include this variable in our analysis. With the advent of computerised step counters, in the future, we should be better able to collect and evaluate objective data to access the role of repetitive trauma from walking as a risk factor and component cause of foot ulcers (45).

Approximately 19% of the ulcers in this study were precipitated by ill-fitting shoe gear. Most of these patients also had sensory neuropathy, as do most patients that develop foot ulcerations. The definition of ill-fitting shoes used in this study probably erred on being conservative because many patients do not know the specific shoes that they wore at the time of ulceration. Therefore, it was not possible to evaluate or measure the patient's shoes that may have been associated with the ulcer. We defined ill-fitting shoes when ulcers developed on the dorsum of the toes or over bony prominences on the medial or lateral aspect of the foot that were not otherwise attributed to direct trauma or injury. These are sites that are not otherwise predisposed to injury unless the area is exposed to

constant pressure or friction from shoes that are too small. Regrettably, it was impossible to measure the role of repetitive minor trauma in the development of ulceration. This concept has been described by Brand as a triad of causative factors that include sensory neuropathy, moderate or high pressures on the sole of the foot and repetitive trauma to the areas of abnormal pressure (46,47). Ideally, the definition of ill-fitting footwear could be expanded to include the concept of inadequate shock absorption or some objective measure of length, width and depth. Unfortunately, these parameters were beyond the scope of this project. Prevention measures for this group would have simply involved having shoes that fit properly and perhaps padded hosiery (48). Most of these patients would not require the expense of traditional therapeutic shoes. Education about proper shoe fit and shoe and lower extremity evaluation by their primary care physician or podiatrist on a regular basis would have been sufficient to reduce the risk of ulceration in many of these patients.

About 11% of all ulcers were precipitated by a puncture injury. Previous studies have indicated that diabetic patients were up to 46 times more likely to have an amputation after a puncture injury compared with patients without diabetes (43,49,50). Previous works have discussed puncture trauma (high pressure over a small area) as an independent means of skin breakdown in diabetic patients (47,51). And previous reports have suggested that as many as 41% of puncture injuries in persons with diabetes occur while the patient is not wearing shoes. These barefoot puncture injuries are more than twice as common in diabetic patients than in patients without diabetes (50). In addition, many of the objects that caused the injury, like needles, thorns, tacks and wood splinters are uncommon in persons without diabetes and most of them probably would not have been able to penetrate the foot if shoes had been worn (43). Again, the importance of foot puncture injuries as pivotal factors in ulcer development suggest that simple preventative and patient education measures may be very effective in reducing this specific pathway.

The majority of the ulcers evaluated in this study were precipitated by way of a pathway that included neuropathy, deformity, callus and elevated plantar pressure. Intuitively, these factors seem to be strongly linked.

Deformity or limited joint mobility (such as hallux rigidus or rigid toe deformities) contribute to elevated pressure areas on the sole of the foot which in turn are often associated with the development of callus (36,44). In the presence of sensory neuropathy, these factors coupled with repetitive injury can cause tissue injury, inflammation, tissue necrosis and finally ulceration. Without neuropathy, pain often limits the number of cycles of repetitive injury before a full-thickness ulcer develops. Several authors have identified an association with limited joint mobility and deformity and foot ulceration in persons with sensory deficits, and callus has been associated with high-pressure areas in persons with diabetes (27–29). The results of the pathway analysis support the notion that these factors are linked.

Several reports have indicated that interventions focused on specific points in this pathway may be effective in reducing the ulcer incidence. Many interventions are directed at reducing peak foot pressure, removing callus on the sole of the foot, and accommodating foot deformities in order to reduce foot pressures. Murray and coworkers indicated that subjects with callus were 11 times more likely to develop ulceration than those without callus (44). In this same study, neuropathic patients were at more than two times greater risk for developing an ulcer in the presence of callus than in the presence of elevated plantar pressure alone (44). Indeed, simple preventive measures such as regular callus debridement can reduce peak plantar pressures by over 25% (36). Furthermore, numerous authors have indicated that appropriately designed shoes can reduce peak pressures to significantly lower levels in neuropathic patients and subsequently reduce ulcer occurrence or recurrence (40,52–59). In a recent study, we noted that certain over-the-counter comfort-type shoes reduced pressure as well or better than depth inlay shoes when fitted with both the stock insoles or with prescription multilaminar insoles (53). In clinical studies, high-risk patients treated with therapeutic footwear re-ulcerated less than half as often as patients that were allowed to select their own footwear (40). It would appear that intervening by merely advising patients to wear appropriate shoe gear, regardless of other risk factors, could result in a significant reduction in the prevalence of lower extremity ulcers.

Some authors have advocated elective surgery to correct foot deformities in diabetic patients in order to heal or prevent diabetic foot ulcers. Armstrong and coworkers indicated that following surgery to correct toe deformities in high-risk diabetics, the incidence of neuropathic ulceration (with a previous history of ulceration) dropped to approximately 2% per annum (60). Likewise, in a descriptive study, Rosenbloom and coworkers (61) described promising results in a series of patients undergoing resectional arthroplasty of the interphalangeal joint of the great toe to heal neuropathic ulcers that had failed conservative therapy. These studies suggest that correction of deformities may also be a valuable adjunct to facilitate ulcer healing and prevent ulcer occurrence or recurrence.

Lower extremity vascular disease has been strongly associated with diabetes-related lower extremity amputations (10). Most clinicians that work in the field of the diabetic foot identify 'ischaemic ulcers' as a separate entity next to 'neuropathic ulcers'. It therefore seems likely that vascular disease is also an important risk factor for foot ulceration. Some studies have indeed linked vascular impairment to diabetic foot ulcers (27). However, recent reports have denied a significant univariate or multivariate association between either micro- or macrovascular disease and development of an ulceration (27,62,63). In this respect, it might be that vascular disease is a risk factor for failure of ulcer healing and thus amputation more than a direct risk factor for ulceration (64). Whatever its exact role, peripheral vascular disease remains a critically important component to be considered during any focused physical examination.

The potential value of this study is that it provides practical criteria to identify common, cogent pathways associated with the development of foot ulcers in persons with diabetes. The data outlined in this study integrate well with previous pathways associated with amputation identified by Pecoraro *et al.* (10) and helps to complete the profile of high-risk patients. This type of information may be used as part of a global thought process in disease management. The results of this study provide a unique perspective for medical directors, physicians and educators. In the pathways identified, interrupting even one key component may mitigate morbidity down the

### Key Points

- many interventions are directed at reducing peak foot pressure, removing callus on the sole of the foot, and accommodating foot deformities in order to reduce foot pressures
- simple preventive measures such as regular callus debridement can reduce peak plantar pressures by over 25%
- appropriately designed shoes can reduce peak pressures to significantly lower levels in neuropathic patients and subsequently reduce ulcer occurrence or recurrence
- these studies suggest that correction of foot deformities may also be a valuable adjunct to facilitate ulcer healing and prevent ulcer occurrence or recurrence
- peripheral vascular disease remains a critically important component to be considered during any focused physical examination
- the potential value of this study is that it provides practical criteria to identify common, cogent pathways associated with the development of foot ulcers in persons with diabetes
- this type of information may be used as part of a global thought process in disease management
- the results of this study provide a unique perspective for medical directors, physicians and educators
- in the pathways identified, interrupting even one key component may mitigate morbidity down the pathway; additionally it provides an avenue to plan and implement intervention and prevention strategies

**Key Points**

- if these data are used as part of a common, treatment-based protocol and risk assessment, the result may be a reduction in the unnecessarily high prevalence of diabetes-related lower extremity ulcerations and their eventual counterpart, lower extremity amputations

pathway. Additionally, it provides an avenue to plan and implement intervention and prevention strategies. The components that make up these pathways are generally easily identifiable on a routine lower extremity physical examination. If these data are used as part of a common, treatment-based protocol and risk assessment (27,65,66), the result may be a reduction in the unnecessarily high prevalence of diabetes-related lower extremity ulcerations and their eventual counterpart, lower extremity amputations.

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