international wound journal

International Wound Journal ISSN 1742-4801

ORIGINAL ARTICLE

Podiatrist care and outcomes for patients with diabetes and foot ulcer†

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Key words
Amputation; Diabetes; Foot ulcer; Podiatrist

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doi: 10.1111/iwj.12021

Gibson TB, Driver VR, Wrobel JS, Christina JR, Bagalman E, DeFrancis R, Garoufalis MG, Carls GS, Gatwood J. Podiatrist care and outcomes for patients with diabetes and foot ulcer. Int Wound J 2014; 11:641–648

Abstract

We examined whether outcomes of care (amputation and hospitalisation) among patients with diabetes and foot ulcer differ between those who received pre-ulcer care from podiatrists and those who did not. Adult patients with diabetes and a diagnosis of a diabetic foot ulcer were found in the MarketScan Databases, 2005–2008. Multivariate Cox proportional hazard models estimated the hazard of amputation and hospitalisation. Logistic regression estimated the likelihood of these events. Propensity score weighting and regression adjustment were used to adjust for potentially different characteristics of patients who did and did not receive podiatric care. The sample included 27 545 patients aged greater than 65+ years (Medicare-eligible patients with employer-sponsored supplemental insurance) and 20 208 patients aged lesser than 65 years (non-Medicare-eligible commercially insured patients). Care by podiatrists in the year prior to a diabetic foot ulcer was associated with a lower hazard of lower extremity amputation, major amputation and hospitalisations in both non-Medicare-eligible commercially insured and Medicare-eligible patient populations. Systematic differences between patients with diabetes and foot ulcer, receiving and not receiving care from podiatrists were also observed; specifically, patients with diabetes receiving care from podiatrists tend to be older and sicker.

Introduction

Foot ulcers are a serious complication in patients with diabetes, with up to a 25% lifetime risk of foot ulceration in patients with diabetes (1). Foot ulcers result from degradation in the integumentary, vascular and nervous systems that typically occur in patients with long-standing diabetes mellitus. This environment permits acute or chronic repetitive trauma to frequently go unrecognised by the patient. If ulcers fail to heal and progress into deep infection or gangrene, amputation of the lower extremity may ensue, resulting in a 6–22% cumulative amputation rate for patients with ulcers (2). Most foot complications leading to lower extremity amputations begin as ulcerations (3,4); therefore, proper preventive foot care is key to the management of diabetes (5). Even so, many patients

†An earlier version of this manuscript was presented as a Late-Breaking Abstract at the American Diabetes Association 70th Scientific Sessions, June 2010, Orlando, FL.

Key Messages

- foot ulcers are a serious complication in patients with diabetes
- in a large sample of individuals with diabetes and foot ulcer, those who received care from podiatrists before the onset of a foot ulcer were less likely to have amputation, major amputation and hospitalisation

- podiatrists have been proposed to serve as gatekeepers for the prevention and management of diabetes-related foot complications
- patients with diabetes and foot ulcer receiving care from podiatrists tend to be older and sicker

with diabetes still do not receive preventive foot care prior to ulceration.

Multidisciplinary care has been described to reduce diabetes-related ulcers and amputations (6) in a variety of health care settings including managed care (7), veteran (8,9), military (10) and Native American (11). As part of a team approach, podiatrists have been proposed to serve as gatekeepers for the prevention and management of diabetes-related foot complications (12,13). A recent analysis of the 5% Medicare sample from 1991 to 2007 suggested visiting a podiatrist as part of a lower extremity care team in the year prior to a lower extremity complication was protective for undergoing lower extremity amputation (14). Additionally, a retrospective cohort study of 485 patients found that the referral of patients with diabetes mellitus and risk factors for ulceration and limb loss to specialty multidiscipline podiatric medical care may be associated with lower rates of ulceration and major amputation in some patients, thereby reducing health care costs (15).

Using a large retrospective database of patients with diabetes in the USA, this study assessed the association between podiatric care in the prevention of adverse events (amputation, major amputation and hospitalisation) related to foot ulcers. Comparisons were made between patients with pre-ulcer podiatric visits and patients without pre-ulcer podiatric visits using regression adjustment and propensity score weighting to control for potential differences between these groups of patients.

Methods

Patients were selected from the *Truven Health MarketScan Research Databases*, which are constructed from fully adjudicated medical and outpatient prescription drug claims. The Commercial Database represents the health care experience of tens of millions of employees and their dependents (annually), covered under a variety of employer-sponsored health plans. The Medicare Supplemental and Coordination of Benefits (COB) Database contains the health care experience of individuals with Medicare supplemental insurance paid by employers. Both the Medicare-covered portion of payment (represented as Coordination of Benefits Amount) and the employer-paid portion are included in this database. The medical claims are linked to outpatient prescription drug claims and person-level enrolment data through encrypted enrollee identifiers. The MarketScan databases conform to the confidentiality requirements of the Health Insurance Portability and Accountability Act of 1996; thus, the study did not require informed consent or Institutional Review Board approval.

Study population

Patients aged 18 years and older enrolled in the MarketScan Commercial or Medicare databases during years 2005–2008 were selected to the study population if they had a diabetes diagnosis according to ICD-9-CM codes appearing on at least one inpatient claim or two outpatient claims separated by at least 30 days (codes are available in Table A1). Claims for procedures that are diagnostic in nature (e.g. laboratory tests) were not used to establish the diabetes diagnosis.

The index date for the analysis was assigned as the date of the first observed visit with a diagnosis code indicating foot ulcer in 2005–2008. Patients with an index date in 2005 were excluded if they had any previous claims with a diagnosis of foot ulcer in the previous year. All patients were required to have at least 1 year of enrolment prior to the index date. Patients switching health plans within the same employer could be followed as they changed plans, and all patients were followed through to their end of enrolment in any health plan offered by the employer or up until 2009, whichever was later.

Patients were grouped into case (podiatry care) or comparison (no podiatry care) if the patient received care from a podiatrist during the year prior to the index diabetic foot ulcer diagnosis. The primary analyses compared patients without any visits to a podiatrist during the year prior to the index date (comparison) with those having one or more visits (case). An examination was conducted of patients who had three or more visits to a podiatrist prior to the index date (case) and compared their outcomes to patients without any podiatric visits. Because provider specialty code was used to identify podiatry visits, patients were excluded from the comparison cohort (no podiatric care) if provider specialty codes were not available.

Patients with any lower extremity amputation in the year prior to the index date were excluded from the study, based on both procedure (defined below) and diagnosis codes. Patients were also excluded from the case cohort if the claim for the initial podiatric visit indicated a foot ulcer. Thus, the study captured new episodes of care for a diabetic foot ulcer and compared outcomes for patients who received care from a podiatrist prior to the index foot ulcer to patients who did not receive care from a podiatrist prior to the index foot ulcer.

Outcome variables

Three outcomes were measured: lower extremity amputation, major amputation and hospitalisation. Lower extremity amputation was identified using procedure codes on the claims. A subset of lower extremity amputations were classified as major amputations, defined as amputations occurring at the knee or higher. Inpatient hospitalisation was indicated by a stay in an inpatient facility including at least one night of room and board. A flag was created to indicate the presence of each outcome during a fixed 24-month follow-up period after the index date for patients who could be followed for at least 24 months. Among patients with each outcome, time in days from index (first observed foot ulcer) to the outcome was measured.

Explanatory variables

Sociodemographic characteristics, plan type, health status and risk factors were also measured. These characteristics included: patient age at index; gender; urban residence (defined as residence in a metropolitan statistical area); and whether the primary beneficiary was paid salaried or hourly and US census region (Northeast, North Central, West and South). Two measures were taken from the 2000 census data: median household income by ZIP code of residence as a proxy for income, and percent of college graduates (among residents aged 25 and older) by ZIP as a proxy for education. Plan types included comprehensive, health maintenance organisation (HMO), point-of-service (POS), preferred provider organisation (PPO) and others (e.g. consumer-directed health plan (CDHP) and capitated POS).

Health status variables were measured during the year prior to index. The Charlson comorbidity index (CCI) is an aggregate measure based on diagnoses associated with 19 conditions (16); however, because the CCI does not capture mental health conditions, the number of Psychiatric Diagnostic Groupings (PDGs) was also included. The 12 PDGs include mental health conditions such as alcohol-use disorders, depression and schizophrenia (17). Refill adherence to antidiabetic medications, as indicated by the percent of days covered with antidiabetic medications on hand, was also captured.

Two sets of risk factors were included in the models and also measured during the year prior to the index foot ulcer diagnosis. Patient-level risk factors included cardiovascular disease, nephropathy and diabetes-related eye disease. Foot-level risk factors included neuropathy, peripheral arterial disease, callus and others (e.g. abrasions) (18). Codes for these conditions are detailed in Table A1.

Propensity score weighting

As patients in the case and comparison groups may be different in terms of demographic characteristics or health status, propensity score weighting was used to adjust for observable differences between the two cohorts in two steps. First, the probability of seeing a podiatrist was estimated using a logistic regression (dependent variable = 1 if case and 0 if comparison), as a function of the explanatory variables. Two other variables were added to the propensity score models: the number of months a patient was followed over time (enrolment months) and the percent of enrolment within the patient's employer × health plan using podiatric services (to account for differences in podiatry benefits). Second, cases were assigned a weight of 1 and comparison patients were assigned a weight of $p/(1-p)$, where p is the predicted probability of being a case from the logistic regression (19). With this weighting, estimates are interpreted as the effect of the treatment (care by a podiatrist) on the treated (those who received care from a podiatrist) (20).

Separate propensity score regressions and weights were calculated for each sample (commercial and Medicare-eligible) and also for each analysis (i.e. main analysis where podiatry care is defined as one or more pre-ulcer visits and the sensitivity analysis that defined podiatry care as three or more pre-ulcer podiatry visits).

Statistical analysis

Two sets of statistical models were estimated. First, Cox proportional hazard models estimated the risk of amputation at time t, conditional on survival (i.e. enrolment) to that time (t), controlling for the explanatory variables. Second, the likelihood of each outcome within a fixed length of follow-up, 2 years after diagnosis of foot ulcer, was estimated using logistic regression and the same covariates as the Cox proportional hazard models, with the addition of the year of the index date. Then, the predicted probability of each outcome was estimated (21). Each of these analyses was conducted with and without propensity score weights within the commercial and Medicare-eligible samples.

Results

We found 20 208 commercially insured patients (7597 with podiatrist care and 12 611 with no podiatrist care) and 27 545 Medicare-eligible patients (13 692 with podiatrist care and 13 853 with no podiatrist care) meeting all inclusion and exclusion criteria, where podiatrist care was defined as one or more visits to a podiatrist during the year prior to the index foot ulcer (Table 1).

In both the commercial and Medicare samples, patients receiving care from podiatrists were older than patients who did not receive pre-ulcer podiatry care (Table 1). Also, a higher percentage of patients receiving care from podiatrists were females ($P < 0{\cdot}001$). Patients receiving care from podiatrists were more likely to reside in an urban area than those who did not receive care from podiatrists ($P < 0{\cdot}001$).

Health status, as indicated by average scores on the CCI and the number of PDGs, was lower and statistically significant ($P < 0{\cdot}001$) for patients receiving care from podiatrists, except that differences in PDGs did not reach statistical significance in the commercial sample ($P = 0{\cdot}212$). A greater proportion of patients receiving care from podiatrists had higher values of patient-level and foot-level risk factors measured (all $P < 0{\cdot}01$) with the exception of nephropathy rates in the Medicare sample where rates did not differ. Adherence to antidiabetic medications, as indicated by a higher medication possession ratio, was greater in patients receiving care from podiatrists ($P < 0{\cdot}001$).

In both the commercial and Medicare samples, patients receiving care from podiatrists had a longer length of time to amputation than those who did not receive such care (Table 1), without adjusting for differences between patients who did and did not receive pre-ulcer podiatric care. The difference was about 55 (Medicare) to 77 (commercial) days longer until amputation for podiatry patients (both $P < 0{\cdot}001$). Results were similar for major amputation, except that differences in the time to amputation were not statistically significant in the commercial sample. Patients seen by a podiatrist also had a longer time to hospitalisation of 35 (Medicare) to 64 (commercial) days (all $P < 0{\cdot}001$).

About 40% of enrollees could be followed over 24 months. The percent of patients with each of the events (amputation or hospitalisation) within 24 months was significantly lower for patients in the podiatry care group for both the commercial and Medicare samples (all $P < 0{\cdot}05$).

Table 1 Comparison of patients with diabetes and foot ulcer (unmatched comparison)*

Characteristic	Commercial			Medicare		
	Podiatrist visit (case)†	No podiatrist visit (comparison)	*P*-value	Podiatrist visit (case)	No podiatrist visit (comparison)	*P*-value
n	7597	12 611		13 692	13 853	
Age group, %						
18–34	1·5	2·3	<0·001			
35–44	6·0	9·7	<0·001			
45–54	30·7	33·1	<0·001			
55–64	61·8	54·8	<0·001			
65–74				35·8	41·6	<0·001
75–84				46·8	44·0	<0·001
>85				17·4	14·4	<0·001
Age, years (mean ± SD)	55·0 ± 6·8	53·7 ±7·6	<0·001	77·6 ±6·9	76·7 ±6·9	<0·001
Female	44·7	38·1	<0·001	48·5	44·4	<0·001
Employee	66·6	68·0	0·037	81·0	81·3	0·565
Insurance plan type, %						
Comprehensive	10·9	9·1	<0·001	56·1	45·8	<0·001
HMO	14·8	21·4	<0·001	7·5	16·7	<0·001
POS/EPO	11·3	8·8	<0·001	1·7	1·1	<0·001
PPO	58·5	56·6	0·009	33·5	34·9	0·014
Other	4·5	4·0	0·093	1·2	1·6	0·003
Urban residence	84·5	80·1	<0·001	86·7	82·4	<0·001
Geographic region, %						
Northeast	16·1	8·9	<0·001	12·5	7·9	<0·001
North Central	31·5	27·5	<0·001	45·0	38·2	<0·001
South	42·4	47·5	<0·001	26·9	32·7	<0·001
West	9·7	15·8	<0·001	15·4	21·0	<0·001
Unknown	0·4	0·3	0·208	0·2	0·2	0·860
Median household income in ZIP, $ (mean ± SD)	45 588 ± 15 579	43 459 ± 14 565	<0·001	45 869 ± 15 403	44 345 ± 14 888	<0·001
Percent college graduates in ZIP (mean ± SD)	0·22 ± 0·13	0·21 ± 0·13	<0·001	0·23 ± 0·13	0·22 ± 0·13	<0·001
Health status‡						
Charlson comorbidity index	2·64 ± 1·74	2·15 ± 1·74	<0·001	3·17 ± 1·99	2·82 ± 1·92	<0·001
Psychiatric diagnosis groups	0·18 ± 0·52	0·17 ± 0·52	0·212	0·19 ± 0·54	0·17 ± 0·50	<0·001
Medication possession ratio	0·64 ± 0·36	0·57 ± 0·38	<0·001	0·65 ± 0·36	0·63 ± 0·37	<0·001
Patient-level risk factors‡, %						
Cardiovascular	61·2	56·6	<0·001	72·1	68·4	<0·001
Nephropathy	16·1	15·0	0·048	20·5	21·3	0·109
Eye	19·3	15·2	<0·001	13·6	11·3	<0·001
Foot-level risk factors‡, %						
Neuropathy	15·0	6·8	<0·001	8·2	5·0	<0·001
Peripheral arterial disease	20·2	17·7	<0·001	32·5	26·6	<0·001
Callus	2·6	1·3	<0·001	3·7	1·3	<0·001
Months of enrolment after index	23·22 ± 15·04	21·85 ± 14·93	<0·001	23·26 ± 15·50	21·24 ± 15·24	<0·001
Year of index date, %						
2005	24·1	23·6	0·418	24·25	28·28	<0·001
2006	23·8	21·9	0·002	26·79	23·92	<0·001
2007	25·3	25·3	0·925	24·81	23·86	0·068
2008	26·8	29·2	<0·001	24·15	23·94	0·675
Measures						
n	7597	12 611		13 692	13 853	
n with lower extremity amputation	811	1682		1042	1240	
Time to amputation (days)	284·0 ± 347·8	207·4 ± 302·6	<0·001	265·2 ± 325·3	210·1 ± 298·0	<0·001
n with major amputation	179	380		280	407	
Time to major amputation (days)	332·5 ± 280·2	271·0 ± 328·4	0·051	278·9 ± 312·3	215·5 ± 284·1	0·006
n with hospitalisation	3475	6451		8576	8592	
Time to hospitalisation (days)	284·3 ± 320·1	220·5 ± 290·2	<0·001	288·4 ± 305·5	253·2 ± 291·5	<0·001
Measures (within 2 years)						
n with 2-year follow-up	3304	4914		5990	5423	
Lower extremity amputation, %	10·3	12·4	0·003	7·2	8·8	0·002
Major amputation, %	1·7	2·5	0·021	1·7	2·7	<0·001
Hospitalisation, %	44·2	51·6	<0·001	58·2	60·2	0·036

HMO, health maintenance organisation; POS, point-of-service; PPO, preferred provider organisation.

*Data source: 2004–2009 MarketScan Databases.

†Cases are patients with one or more visits to a podiatrist during the year prior to their index foot ulcer. Comparison patients did not have visits to a podiatrist during the year prior to their index foot ulcer.

‡Measured 1 year prior to index date.

After adjusting for covariates, patients receiving care from podiatrists had lower rates of amputation, major amputation and hospitalisation than those who did not receive care from podiatrists in all model specifications: the unweighted and propensity score-weighted analyses for both the commercial and Medicare samples (all $P < 0{\cdot}001$) (Table 2). For example, patients receiving care from podiatrists in the commercial unweighted sample had a hazard of amputation that was 25·2% lower than patients without podiatric care [hazard ratio (HR) = 0·748, 95% confidence interval (CI): 0·686–0·816] and 20·6% lower for the Medicare unweighted sample (HR = 0·794, 95% CI: 0·729–0·864). Results were similar for the weighted samples. Commercial patients receiving pre-ulcer care from a podiatrist had a 25·0% lower hazard of lower extremity amputation than patients without care from a podiatrist in the commercial weighted sample – this was 23·4% for the Medicare weighted sample.

To assess whether a greater number of pre-ulcer podiatric visits had a larger effect on the events, we conducted a sensitivity analysis comparing patients with three or more pre-ulcer podiatric visits to the comparison group without pre-ulcer visits to a podiatrist. Hazard ratios estimated in the sensitivity analysis were similar to the main analysis comparing patients with one pre-ulcer podiatric visit to patients without podiatric visits. Patients with three or more pre-ulcer podiatric visits in the weighted commercial sample had 23·7% lower risk of lower extremity amputation (HR = 0·763, 95% CI: 0·688–0·845) and a 25·7% lower hazard in the weighted Medicare sample (HR = 0·743, 95% CI: 0·675–0·817) than the comparison group (26·2% and 23·7% in the unweighted commercial and Medicare samples, respectively).

Kaplan–Meier curves for lower extremity amputation are shown in Figure 1 (weighted samples) and show that the patients with a podiatrist visit had a longer time to amputation than those without podiatry visits for both the commercial (Panel A) and Medicare (Panel B) samples.

For the sample of patients with at least 2 years of follow-up after the index date, the likelihood of each event (amputation or hospitalisation) occurring within 2 years of the index date was significantly lower in patients receiving care from podiatrists (all $P < 0{\cdot}01$) in both the commercial and Medicare propensity score-weighted samples (Figure 2). Similar results were found in the unweighted samples (all $P < 0{\cdot}01$, not shown).

Discussion

Podiatrists are medical practitioners focusing on management and treatment of the foot and are considered by many health care professionals to be the primary source of specialised foot care in the USA. The more recent practice model developed by the medical community describes the podiatrist as a 'Limb Preservationist' (13). This new model focuses not only on the contribution of podiatrists but also on several members of an interdisciplinary team that medically and surgically manages complicated and complex diabetic foot disorders.

In this study of two large samples of individuals with diabetes and foot ulcer (commercially insured and Medicare-eligible), we found that those who received care

Table 2 Adjusted hazard ratios (HRs) associated with pre-period podiatric medical care for patients with diabetes and foot ulcer*

	Unweighted Samples						Weighted Samples					
	Commercial			Medicare			Commercial			Medicare		
Event	Adj. HR	*P*-value	95% CI	Adj. HR	*P*-value	95% CI	Adj. HR	*P*-value	95% CI	Adj. HR	*P*-value	95% CI
1+ Podiatry visit												
	n = 7597 podiatrist visit (case) *n* = 12 611 no podiatrist visit (comparison)			*n* = 13 692 podiatrist visit (case) *n* = 13 853 no podiatrist visit (comparison)			*n* = 7597 podiatrist visit (case) *n* = 12 611 no podiatrist visit (comparison)			*n* = 13 692 podiatrist visit (case) *n* = 13 853 no podiatrist visit (comparison)		
Lower extremity amputation	0·748	<0·001	0·686–0·816	0·796	<0·001	0·730–0·867	0·747	<0·001	0·687–0·811	0·769	<0·001	0·705–0·839
Major amputation	0·690	<0·001	0·575–0·828	0·661	<0·001	0·564–0·774	0·691	<0·001	0·578–0·825	0·652	<0·001	0·555–0·766
Hospitalisation	0·722	<0·001	0·692–0·754	0·863	<0·001	0·837–0·890	0·729	<0·001	0·699–0·759	0·839	<0·001	0·813–0·866
3+ Podiatry visits												
	N = 3994 podiatrist visit (case) *N* = 12 611 no podiatrist visit (comparison)			*n* = 7652 podiatrist visit (case) *n* = 13 853 no podiatrist visit (comparison)			*n* = 3994 podiatrist visit (case) *n* = 12 611 no podiatrist visit (comparison)			*n* = 7652 podiatrist visit (case) *n* = 13 853 no podiatrist visit (comparison)		
Lower extremity amputation	0·738	<0·001	0·660–0·824	0·766	<0·001	0·691–0·850	0·757	<0·001	0·683–0·839	0·749	<0·001	0·681–0·824
Major amputation	0·732	0·007	0·584–0·919	0·618	<0·001	0·508–0·751	0·747	0·007	0·605–0·923	0·614	<0·001	0·511–0·737
Hospitalisation	0·713	<0·001	0·675–0·753	0·826	<0·001	0·796–0·857	0·743	<0·001	0·707–0·781	0·800	<0·001	0·773–0·828

*Data source: 2004–2009 MarketScan Databases.

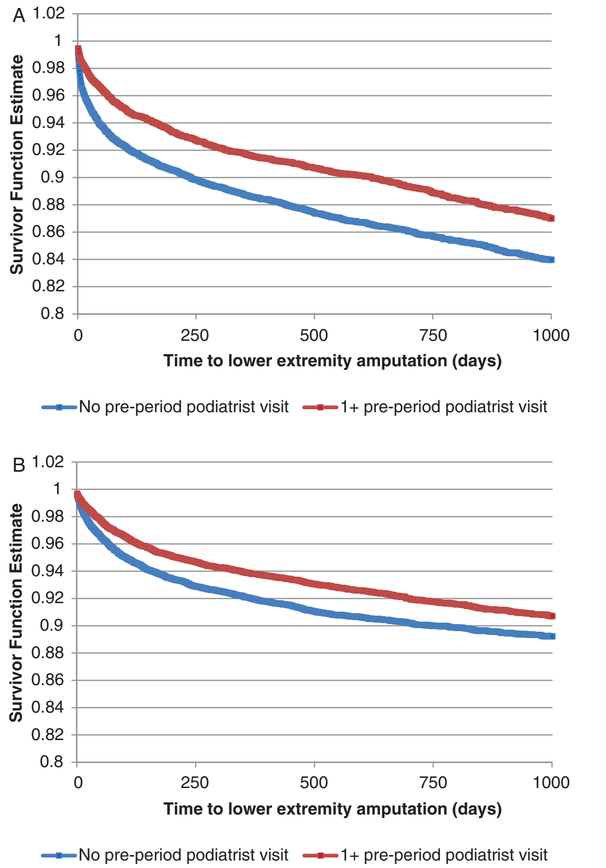

Figure 1 Kaplan–Meier curve for time to lower extremity amputation. (A) Commercially insured patients ($n = 7597$ case, $n = 12\,611$ comparison). (B) Medicare-eligible patients ($n = 13\,692$ case, $n = 13\,853$ comparison). Data source: 2004–2009 MarketScan Databases. Estimates are shown using propensity score weights to account for differences between case and comparison patients. Podiatry care group had one or more podiatry visits during the year prior to the index foot ulcer diagnosis; the no podiatry group had no such visits.

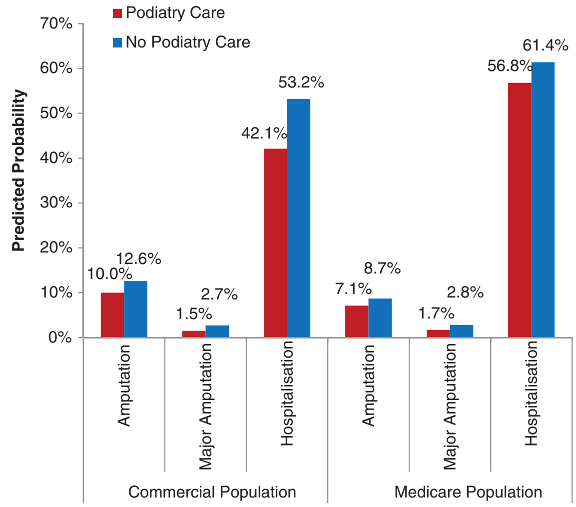

Figure 2 Predicted probability of outcome within 2 years, weighted samples. Data source: 2004–2009 MarketScan Databases. All comparisons between podiatry care and no podiatry care were statistically significant at $P < 0{\cdot}01$. Estimates are shown using propensity score weights to account for differences between case and comparison patients. Podiatry care group had one or more podiatry visits during the year prior to the index foot ulcer diagnosis; the no podiatry group had no such visits.

from podiatrists before the onset of a foot ulcer were less likely to have adverse events such as amputation, major amputation and hospitalisation. We also found that there were systematic differences between patients with diabetes and foot ulcer receiving care from podiatrists and patients with diabetes and foot ulcer who did not receive care from podiatrists. Namely, patients with diabetes receiving care from podiatrists tend to be older and sicker than those who do not receive care from podiatrists. Adjusting for these differences via regression adjustment or a combination of propensity score weighting and regression adjustment yielded similar results – a significant reduction in the likelihood of and time to each of the adverse events.

Our findings are in agreement with results observed in previous studies of podiatric care and lower extremity amputations. Sloan *et al.* assessed a 5% sample of Medicare claims between 1991 and 2007 for patients with diabetes-related lower extremity complications. The study authors concluded that patients having received care from both a podiatrist and a lower extremity care specialist for an ulceration were 36% less likely to have had a lower extremity amputation compared to those who had only seen another type of physician (14). In the same study, those with care provided by only a podiatrist were also less likely to have had a lower extremity amputation (44% less likely) but this was not statistically significant. This study shows a lower likelihood of amputation after receipt of podiatric care, but we are unable to distinguish patients who receive other specialised lower extremity care from those who do not.

More recently, Carls *et al.* also examined the effects of podiatric care in the treatment of diabetic foot ulcers, including populations of commercially insured and Medicare patients. This analysis observed that podiatric care was associated with a 2·67 and 1·35 percentage point reduction in amputation rates in a commercially insured and Medicare-eligible population, respectively (22).

Several other studies also address the value of podiatric care. A study of 91 patients in Austria with recently healed foot ulcers and diabetes found a significant reduction in the amount of time to ulcer recurrence among patients randomised to podiatrist care (HR: 0·52, 95% CI: 0·30–0·93) (23). A second study analysed the experience of 530 patients in Finland who were receiving antidiabetes medications, but had no obvious need for a podiatrist. Half the sample was randomised to receive podiatrist care and the other half to receive written instructions (24). At the end of 1-year follow-up, the prevalence of callosities in regions other than the calcaneal region decreased, as did the diameter of these callosities in patients receiving care from podiatrists. Lavery *et al.* (7) reported that a team including podiatrists implemented a foot risk-based disease management program for diabetes foot care in a US-managed care program and after 2 years, there was a 47% reduction in amputations, 38% reduction in hospital admissions and 70% reduction in skilled nursing facility admissions.

There are potential limitations to this analysis. First, we did not extract the specific features of care or other types of providers involved in the ulcer care. We measured receipt of care from podiatrists prior to the onset of a foot ulcer to determine whether these process differences led to differences in outcomes. The aim of this study was to measure podiatry in terms of its educational and holistic benefits during a subsequent ulceration, not to measure process of care differences within the episode of care. This strategy is supported in the literature as podiatry care in patients with diabetes resulted in higher knowledge scores and higher self-care scores at 1 year (24). This is also supported in this study as patients seeing podiatrists were also more adherent to medication use as indicated by significantly higher medication possession ratios. Second, we focused our analysis on those patients with foot ulcer who did not have an amputation or an ulcer in the previous year, which may limit generalisability to other patient populations. However, this also underscores the magnitude of these findings as patients with a previous foot ulcer tend to be sicker than patients without a history of foot ulcer, an observation supported by the significant differences in CCI between our case and comparison cohorts. Third, our results are based on administrative claims data, and all the limitations inherent in coding systems and data designed for reimbursement apply to this study.

In summary, in a sample of patients with diabetes and foot ulcer, we found that pre-ulcer care by a podiatrist appears to be associated with lower rates of lower extremity amputation and hospitalisation.

Acknowledgements

This study was funded by American Podiatric Medical Association. TG, EB, GC and JG were salaried employees of Thomson Reuters (now Truven Health Analytics) at the time the study was conducted – Thomson Reuters was under contract for the study funded by the American Podiatric Medical Association (APMA); TG has been involved in projects sponsored by Pfizer Inc and Bristol Myers Squibb; VD is a Volunteer Position Chair for Clinical Practice Guidelines for the APMA; JW is a member of the Clinical Practice Advisory Committee (CPAC) for the APMA; JC is the Director of Scientific Affairs at the APMA; RD does not have conflicts of interest to report and MG is a trustee for APMA.

Author contribution

TG researched data, contributed to the discussion, wrote the manuscript and reviewed/edited the manuscript; VD researched data, contributed to the discussion, wrote the manuscript and reviewed/edited the manuscript; JW contributed to the discussion and reviewed/edited the manuscript; JC contributed to the discussion and reviewed/edited the manuscript; EB researched data, contributed to the discussion and reviewed/edited the manuscript; RD contributed to the discussion and reviewed/edited the manuscript; MG contributed to the discussion and reviewed/edited the manuscript; GC contributed to the discussion, reviewed data and reviewed/edited the manuscript and JG researched data and contributed to the results. All authors provided final approval of the version to be published.

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APPENDIX

Table A1 Codes for patient-level and foot-level risk factors*

Category	ICD-9	Description
Codes applied for patient-level risk factors		
Cardiology	401.xx	Essential hypertension
Cardiology	402.xx	Hypertensive heart disease
Cardiology	403.xx	Hypertensive renal disease
Cardiology	404.xx	Hypertensive heart and renal disease
Cardiology	405.xx	Secondary hypertension
Cardiology	415.0x	Coronary artery disease
Cardiology	414.00	Arteriosclerotic heart disease
Cardiology	428.0	Congestive heart failure
Cardiology	429.2	Arteriosclerotic cardiovascular disease
Cardiology	429.9	Heart disease, unspecified
Eye	362.0x	Retinopathy
Nephropathy	580.xx	Acute glomerulonephritis
Nephropathy	581.xx	Nephrotic syndrome
Nephropathy	582.xx	Chronic glomerulonephritis
Nephropathy	583.xx	Nephritis and nephropathy not specified
Nephropathy	584.xx	Acute renal failure
Nephropathy	585.xx	Chronic renal failure
Nephropathy	586.xx	Renal failure unspecified
Nephropathy	587.xx	Renal sclerosis unspecified
Nephropathy	588.xx	Disorders resulting from impaired renal functioning
Nephropathy	589.xx	Small kidney of unknown cause
Codes applied for foot-level risk factors		
Callus	700	Corn, clavus, callus
Neuropathy	355.0	Peripheral neuritis/neuralgia, acute, sciatic nerve
Neuropathy	355.2	Peripheral neuritis/neuralgia, acute, femoral nerve
Neuropathy	355.3	Peripheral neuritis/neuralgia, acute, lateral popliteal nerve
Neuropathy	355.4	Peripheral neuritis/neuralgia, acute, medial popliteal nerve
Neuropathy	355.5	Peripheral neuritis/neuralgia, acute, posterior tibial nerve
Neuropathy	355.6	Peripheral neuritis/neuralgia, acute, plantar nerve
Neuropathy	355.7	Peripheral neuritis/neuralgia, acute, due to infection
Neuropathy	355.79	Peripheral neuritis/neuralgia, acute, saphenous nerve
Neuropathy	355.8	Peripheral neuritis/neuralgia, acute, lower limb, polyneuritis
Neuropathy	357.2	Polyneuropathy in diabetes (always code first the diabetes, 250.6X)
Neuropathy	357.4	Polyneuropathy in other diseases classified elsewhere (code underlying disease first)
Neuropathy	713.5	Charcot
Neuropathy	782.0	Numbness
PAD	440.20	Arteriosclerosis/atherosclerosis, unspecified
PAD	440.21	Arteriosclerosis/atherosclerosis with intermittent claudication
PAD	440.22	Arteriosclerosis/atherosclerosis, with rest pain
PAD	440.23	Arteriosclerosis/atherosclerosis with ulceration (use additional code 707.10-707.9)
PAD	440.24	Arteriosclerosis/atherosclerosis, with gangrene
PAD	440.4	Artery of the extremities, chronic total occlusion
PAD	443.1	Buerger's disease
PAD	443.81	Peripheral vascular disease of diabetes (code underlying diabetes first 250.7X)
PAD	443.9	Peripheral vascular disease
PAD	451.0	Phlebitis, superficial
PAD	451.11	Phlebitis, femoral vein (deep) (superficial)
PAD	451.19	Phlebitis, other (femoropopliteal vein, tibial vein, popliteal vein)
PAD	451.2	Phlebitis, unspecified
PAD	454.0	Varicose vein, with ulceration
PAD	454.1	Stasis dermatitis, with inflammation
PAD	454.2	Varicose vein, with ulceration and inflammation
PAD	454.8	Varicose vein with other complications (oedema, pain, swelling)
PAD	454.9	Varicose vein, asymptomatic
PAD	459.11	Postphlebitic syndrome with ulcer
PAD	459.12	Postphlebitic syndrome with inflammation
PAD	459.13	Postphlebitic syndrome with ulcer and inflammation
PAD	459.81	Venous insufficiency (use additional code for any associated ulcer 707.10-707.9)

PAD, peripheral artery disease.
*Other Codes: Diabetes: ICD-9-CM: 250.xx (exclude: 648.8x). Foot ulcer: ICD-9-CM: 707.10, 707.12, 707.13, 707.14, 707.15. Lower extremity amputation: ICD-9-CM: 84.11; CPT-4: 10180, 12020, 12021, 27880, 27881, 27882, 27884, 27886, 27888, 28116, 28126, 28153, 28160, 28800, 28805, 28810, 28820, 28825. Major amputation: CPT-4: 27880, 27881, 27882.