The Association Between Geographic Density of Infectious Disease Physicians and Limb Preservation in Patients With Diabetic Foot Ulcers

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Background. Avoiding major (above-ankle) amputation in patients with diabetic foot ulcers is best accomplished by multidisciplinary care teams with access to infectious disease specialists. However, access to infectious disease physicians is partially influenced by geography. We assessed the effect of living in a hospital referral region with a high geographic density of infectious disease physicians on major amputation for patients with diabetic foot ulcers. We studied geographic density, rather than infectious disease consultation, to capture both the direct and indirect (eg, informal consultation) effects of access to these providers on major amputation.

Methods. We used a national retrospective cohort of 56 440 Medicare enrollees with incident diabetic foot ulcers. Cox proportional hazard models were used to assess the relationship between infectious disease physician density and major amputation, while controlling for patient demographics, comorbidities, and ulcer severity.

Results. Living in hospital referral regions with high geographic density of infectious disease physicians was associated with a reduced risk of major amputation after controlling for demographics, comorbidities, and ulcer severity (hazard ratio, .83; 95% confidence interval, .75–.91; *P* < .001). The relationship between the geographic density of infectious disease physicians and major amputation was not different based on ulcer severity and was maintained when adjusting for socioeconomic factors and modeling amputation-free survival.

Conclusions. Infectious disease physicians may play an important role in limb salvage. Future studies should explore whether improved access to infectious disease physicians results in fewer major amputations.

Keywords. geographic variation; infectious disease providers; major amputation; multidisciplinary teams.

Infection has been termed the "coup de grace" for patients with diabetic foot ulcers, leading to major (above-ankle) amputation [1–4]. Approximately one quarter of the 24 million Americans with diabetes develop a foot ulcer during their lifetime, and 4% undergo major amputation [5, 6]. This rate is 7-fold higher than among patients without diabetes [7]. Not only is major amputation associated with decreased function and an estimated 50% 5-year mortality rate, each episode costs the US healthcare system $53 779 (2012 US dollars [8–10]). Given the associated morbidity, mortality, and economic cost, limb preservation in the setting of a diabetic foot ulcer has become a national healthcare priority. Lower extremity amputation in diabetics is an ambulatory care sensitive condition, and reducing amputations is a Healthy People 2020 goal [11, 12].

The Infectious Disease Society of America (IDSA) guidelines for the diagnosis and treatment of diabetic foot ulcer infections recommends management by multidisciplinary teams with access to infectious disease specialists to prevent limb loss [2, 13]. Infectious disease physicians offer expertise in the management of complex infections known to precipitate major amputation. However, access to infectious disease physicians is partially influenced by geography. Major amputation rates also fluctuate across the United States, varying 8.6-fold between tertiary care center catchments [5, 14]. In Europe, the geographic variation in amputation can only partially be explained by differences in disease severity at presentation [15]. The reason for geographic-based variation is unknown, but it is potentially driven by both local medical cultures and access to specialists [5, 14].

Our objective was to determine whether access to infectious disease physicians influenced the hazard of major amputation for patients with diabetic foot ulcers. We hypothesized that regions with a high density of infectious disease physicians would have lower rates of major amputations among persons presenting with diabetic foot ulcers. We analyzed the geographic density of infectious disease physicians, rather than the direct impact of infectious disease consultation alone, because it is likely that these specialists also indirectly affect the approach to diabetic foot ulcers via medical culture, stewardship activities, and informal consults [16–19].

PATIENTS AND METHODS

Data Sources

We used a 5% random national sample of Medicare beneficiaries from January 1, 2004 to December 31, 2011, obtained through the Centers for Medicare and Medicaid Services Chronic Condition Data Warehouse. Medicare enrollment and claims data were linked by patients' 5-digit ZIP code of residence to hospital referral regions (HRRs), obtained through the Dartmouth Atlas [20]. Hospital referral regions represent the regional catchment areas for tertiary medical care provided at major referral centers. Each of the 306 HRRs contains at least 1 city where both major cardiovascular surgery and neurosurgery are performed. For the year 2006, the total number of Medicare enrollees in each HRR was obtained from the Centers for Medicare and Medicaid Services and the Dartmouth Atlas, which make the data publicly available [21]. The total number of practicing infectious disease physicians in 2006 and their 5-digit ZIP codes were obtained from the American Medical Association, allowing specialists to be assigned to a hospital referral region. Rural/urban commuting area (RUCA) codes, made publicly available through the Rural Health Research Center, were assigned to each patient using their 5-digit ZIP codes [22]. The RUCA codes represent rural/urban gradients of ZIP codes categorized as urban core, suburban, large town, small town, or isolated rural areas [23].

Study Design

We identified a retrospective, national rolling cohort of Medicare beneficiaries who were diagnosed with incident diabetic foot ulcer between January 1, 2006 and December 31, 2011 [24]. Diabetic foot ulcers were categorized as early stage, osteomyelitis, or gangrene (*International Classification of Diseases, 9th Revision* [ICD-9] codes are listed in the Appendix). Additional inclusion criteria were as follows: age ≥65 years at the time of ulceration, continuous Medicare parts A and B coverage during the 2-year baseline period before ulceration, and known to have diabetes during the baseline period [25]. Patients were identified as having diabetes if they had at least 1 inpatient or skilled nursing facility claim or more than 1 professional service claim in 24 months for the following ICD-9 codes: 250.xx, 357.2, 362.0x, 366.41, or 648.0x [25]. Patients were excluded if they were diagnosed with a foot ulcer or underwent major amputation during the baseline; this was to identify a population with incident diabetic foot ulcers, because most ulcerations that relapse do so within 2 years [26]. Railroad retirement beneficiaries, those with missing ZIP codes, and patients residing in US territories were also excluded. Patients were followed from the date of diabetic foot ulcer diagnosis until major amputation, death, loss of Medicare parts A and B coverage, or the end of the study period (December 31, 2011).

Primary Outcome

The time to major amputation was measured as the number of days from ulcer diagnosis to major amputation. The ICD-9 procedure codes and the following current procedural terminology codes were used to identify patients with major amputations: 27880, 27881, 27882, 27886, 27888, 27889, 27295, 27590, 27591, 27592, 27596, and 27598 [24, 27].

Primary Explanatory Variable

The geographic density of infectious disease specialists was calculated as the number of infectious disease physicians per 10 000 Medicare enrollees in a patient's HRR. The HRRs were then dichotomized into those above (high) and below (low) the median density of infectious disease physicians. The median, rather than the mean, was used because the distribution of infectious disease physician density was skewed to the right.

Covariates

All covariates were determined at the time of incident foot ulcer diagnosis. These included patient age, sex, race, ulcer severity at presentation (early stage, osteomyelitis, or gangrene), presence of uncomplicated diabetes, and prior myocardial infarction, ischemic heart disease, stroke, or eye disease [24, 27, 28]. The ICD-9 codes used to identify covariates are listed in the Appendix. Patient were considered engaged if they saw a primary care provider at least twice during the 2-year baseline period. The urbanicity of patients' primary residence was characterized using RUCA codes.

Statistical Analysis

We described patient sociodemographics, ulcer severity, comorbid conditions, healthcare engagement, and reason for censoring both overall and stratified by low and high infectious disease physician density. We identified and mapped HRR outliers, areas with very high or low densities of infectious disease physicians, by the blocked adaptive computationally efficient outlier nominators algorithm [29]. This iterative method detected outliers by starting with a small subset of HRRs assumed not to contain outliers and then steadily increasing the subset. Each time an HRR was added, the difference between that single HRR's geographic density of infectious disease physicians and the standard deviation of infectious disease physician density for the growing subset population was calculated. The HRRs with the largest absolute differences were identified as outliers.

We used Cox proportional hazard models to identify the independent effect of infectious disease geographic density on time to major amputation, controlling for all covariates detailed above. We examined whether the effect of infectious disease physician density would be most pronounced for those presenting with osteomyelitis by constructing a secondary model including interaction terms between infectious disease physician density and ulcer severity. Because a large percentage of patients were expected to die during

the study period, and those deaths were likely to be in sicker patients with a higher probability of undergoing major amputation had they survived, we also modeled amputation-free survival. The outcome for this analysis was the number of days from ulcer diagnosis to either major amputation or death. Lastly, we conducted a sensitivity analysis to better control for socioeconomic factors, which may vary by geography and affect the risk of major amputation. We used the area deprivation index, which is a composite measure of 17 US Census indicators of poverty, education, housing, and employment [30]. Values range from 0 to 100, with higher numbers indicative of more deprived areas. The index has been correlated with other health outcomes including all-cause mortality, rehospitalizations, and disease prevalence. We did not include the area deprivation index in our main model because 20.88% of our sample had missing data for this variable, which was not random. A higher proportion of patients living in rural or suburban areas were missing area deprivation index values, which may be attributable to the greater use of post office boxes in these areas. Statistical analyses were performed using Stata version 13.1 (StataCorp LP, College Station, TX).

Ethics

The University of Wisconsin Health Sciences Institutional Review Board approved this study.

RESULTS

Descriptive Summary

A total of 56 440 patients were included in the cohort, with a mean follow-up time of 23.4 months. A total of 6578 practicing infectious disease physicians were identified in 2006. The median number of infectious disease physicians per 10 000 Medicare beneficiaries in an HRR was 1.09 and ranged from 0 to 7.61. A total of 41 050 (72.73%) patients lived in HRR above the median geographic density of infectious disease physicians, and 15 390 (27.27%) patients resided in HRR below the median. Eight HRRs were low-density outliers, all of which had no infectious disease physicians. Sixty HRRs were high-density outliers, with the highest density of infectious disease physicians located in Washington, DC (Figure 1).

Compared with patients residing in areas of low infectious disease physician density, those living in HRRs with high infectious disease physician density were slightly older, more racially diverse, and had a higher proportion of urban dwellers (Table 1). They had higher rates of myocardial infarcts, ischemic
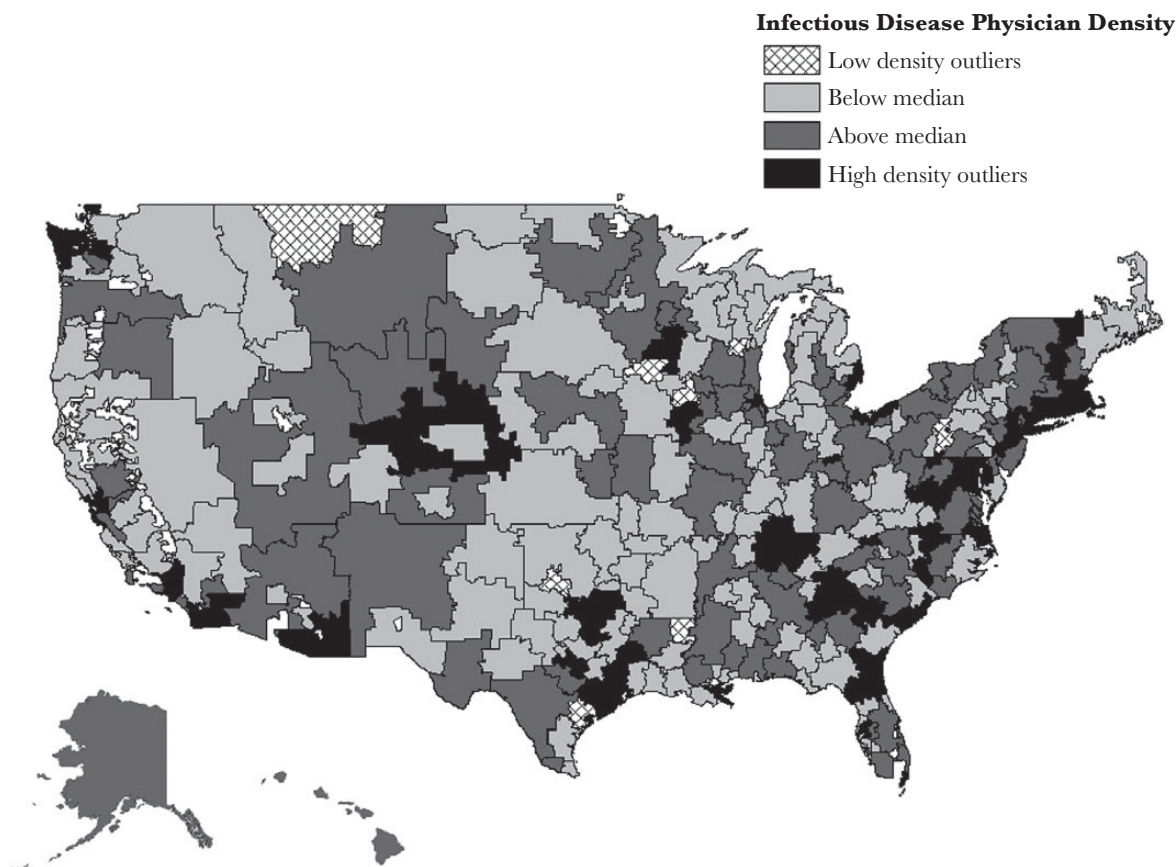
Figure 1. Geographic density of infectious disease physicians in each hospital referral region (HRR) within the United States, 2006. Density was characterized as above or below the median (1.09/10 000 Medicare enrollees in a HRR). Outliers were identified using the blocked adaptive computationally efficient outlier nominators algorithm.

Table 1. Patient Characteristics[a]

Characteristic	Percentage of Total Cohort (N = 56 440)	Percentage of the Subset Residing in an HRR With Below/Above Median Infectious Disease Physician Density	
		Below Median (N = 15 390)	Above Median (N = 41 050)
Age, year, mean (SD)	79.1 (7.8)	78.6 (7.7)	79.3 (7.8)
Female	60.0	58.4	60.5
Race			
White	81.8	86.8	80.0
Black	13.0	9.2	14.4
Other	5.2	4.1	5.6
Area of residence			
South Atlantic	21.4	17.6	22.9
Middle Atlantic	19.0	7.4	23.3
East North Central	18.4	17.9	18.5
West South Central	10.9	20.5	7.3
Pacific	9.5	9.7	9.4
East South Central	6.1	8.5	5.1
West North Central	5.9	10.1	4.4
New England	5.1	1.9	6.3
Mountain	3.8	6.4	2.8
Urbanicity			
Urban core area	68.2	48.3	75.6
Large town area	11.6	19.4	8.7
Suburban area	8.3	10.5	7.5
Small town/ rural	11.5	21.6	7.7
Ulcer severity			
Early	91.6	92.0	91.5
Osteomyelitis	4.6	4.6	4.7
Gangrene	3.8	3.4	3.9
Uncomplicated diabetes	27.0	28.1	26.6
Prior myocardial infarct	29.3	28.1	29.8
Ischemic heart disease	86.6	85.9	86.8
Prior stroke	39.5	36.6	40.6
History of eye disease	30.7	30.9	30.6
At least 2 visits with a primary care provider in the 2-year baseline period	91.2	92.7	90.6
Reason for censoring			
End of study period	52.2	50.8	52.7
Death	38.3	38.8	38.1
Loss of Medicare coverage	5.1	5.3	5.1
Major amputation	4.4	5.1	4.2

Abbreviations: HRR, hospital referral region; SD, standard deviation.

[a]Data are presented as percentage unless otherwise indicated.

heart disease, and stroke; a higher proportion presented with gangrene. A smaller percentage of patients in high-density HRRs, compared with those in low-density HRRs, saw a primary care physician at least twice in the 2-year baseline period. Of the entire cohort, 4.4% underwent major amputation during the follow-up period and 38.3% died.

Association Between Geographic Density of Infectious Disease Physicians and Major Amputation

Patients residing in HRRs with high infectious disease physician density experienced fewer major amputations and death compared with those residing in HRRs with low infectious disease physician density (Table 1). Residing in an HRR with a high compared with low density of infectious disease physicians was protective against major amputation in the primary multivariate Cox proportional hazard model (hazard ratio [HR], .83; 95% confidence interval [CI], .75–.91; $P < .001$) (Table 2). Compared with early-stage ulcers, patients presenting with osteomyelitis or gangrene were significantly more likely to undergo major amputation, respectively (HR = 1.98, 95% CI = 1.69–2.32, $P < .001$; HR = 9.57, 95% CI = 8.58–10.68, $P < .001$). However, including interaction terms between these variables indicated that the protective effect of residing in an HRR with high infectious disease physician density

Table 2. Factors Associated With Major Amputation After Diagnosis of a Diabetic Foot Ulcer, Identified Using Cox Proportional Hazard Modeling

Characteristic	Percentage of Patients Who Did Not Undergo Major Amputation (N = 53 943)	Percentage of Patients Who Underwent Major Amputation (N = 2497)	Unadjusted Hazard Ratio	Main Model Multivariate Hazard Ratio (95% CI)	Main Model Multivariate P Value	Sensitivity Model[a] Multivariate Hazard Ratio (95% CI)	Sensitivity Model Multivariate P Value
Residing in an HRR with below median infectious disease physician density	27.1	31.7	Ref				
Residing in an HRR with above median infectious disease physician density	72.9	68.3	0.80	0.83 (0.75–0.91)	<.001	0.87 (0.77–0.97)	.015
Age, year, mean (SD)	79.2 (7.8)	77.3 (7.4)	0.98	0.996 (0.991–1.002)	.22	0.997 (0.990–1.004)	.40
Female	60.4	50.7	0.65	0.69 (0.63–0.75)	<.001	0.66 (0.59–0.72)	<.001
Race							
White	82.8	61.3	Ref				
Black	12.1	31.4	3.48	2.83 (2.56–3.12)	<.001	2.54 (2.25–2.86)	<.001
Other	5.1	7.3	1.92	1.76 (1.49–2.08)	<.001	1.68 (1.39–2.04)	<.001
Area of residence							
South Atlantic	21.3	24.4	Ref				
Middle Atlantic	19.2	13.8	0.63	0.70 (0.61–0.81)	<.001	0.74 (0.63–0.88)	<.001
East North Central	18.6	14.3	0.70	0.77 (0.67–0.88)	<.001	0.79 (0.68–0.93)	.004
West South Central	10.6	16.4	1.40	1.22 (1.07–1.41)	.004	1.25 (1.06–1.47)	.007
Pacific	9.5	8.6	0.81	0.82 (0.69–0.97)	.02	1.02 (0.84–1.25)	.82
East South Central	5.9	10.1	1.55	1.32 (1.12–1.56)	.001	1.39 (1.15–1.68)	.001
West North Central	6.0	5.6	0.85	1.08 (0.89–1.32)	.42	1.18 (0.95–1.46)	.14
New England	5.2	3.9	0.67	0.85 (0.68–1.07)	.17	0.94 (0.73–1.20)	.60
Mountain	3.9	2.8	0.59	0.75 (0.58–0.98)	.04	0.73 (0.52–1.02)	.06
Urbanicity							
Urban core area	68.5	61.8	Ref				
Large town area	11.5	14.8	1.41	1.47 (1.29–1.67)	<.001	1.34 (1.16–1.56)	<.001
Suburban area	8.3	8.5	1.14	1.19 (1.02–1.39)	.025	1.13 (0.94–1.36)	.21
Small town/ rural	11.4	14.5	1.37	1.35 (1.18–1.55)	<.001	1.23 (1.03–1.46)	.02
Ulcer severity							
Early	92.8	66.8	Ref				
Osteomyelitis	4.5	7.1	2.10	1.98 (1.69–2.32)	<.001	1.98 (1.64–2.37)	<.001
Gangrene	2.7	26.2	12.88	9.57 (8.58–10.68)	<.001	9.95 (8.79–11.26)	<.001
Uncomplicated diabetes	27.7	12.2	0.38	0.49 (0.43–0.56)	<.001	0.49 (0.42–0.57)	<.001
Prior myocardial infarct	28.5	46.2	2.29	1.65 (1.51–1.80)	<.001	1.69 (1.53–1.86)	<.001
Ischemic heart disease	86.2	94.3	2.77	1.77 (1.47–2.13)	<.001	1.93 (1.55–2.39)	<.001
Prior stroke	38.8	54.6	1.94	1.54 (1.42–1.69)	<.001	1.58 (1.43–1.75)	<.001
History of eye disease	30.2	40.8	1.53	1.23 (1.13–1.34)	<.001	1.28 (1.16–1.41)	<.001
Less than 2 visits with a primary care provider in the 2-year baseline period	8.61	13.38	1.59	1.42 (1.25–1.61)	<.001	1.48 (1.28–1.70)	<.001
Area deprivation index, mean (SD)[b]	91.0 (23.8)	97.6 (17.8)	1.02			1.01 (1.005–1.011)	<.001

Abbreviations: CI, confidence interval; HRR, hospital referral region; Ref, reference category; SD, standard deviation.

[a] The sensitivity model controls for the area deprivation index and all other covariates included in the main model.

[b] Area deprivation index data were available for 44 655 patients, 1920 of whom underwent major amputation.

did not vary based on ulcer severity. Living in an HRR with high infectious disease physician density remained protective against major amputation in the sensitivity analysis, which controlled for sociodemographic factors using the area deprivation index (HR, .87; 95% CI, .77–.97; *P* = .015) (Table 2). In the multivariate analysis modeling amputation-free survival, residing in an HRR with a high density of infectious disease physicians remained statistically significant, but the magnitude of protection was diminished (HR, .94; 95% CI, .91–.97; *P* < .001) (Table 3).

Association Between Place of Residence and Major Amputation

Geographic differences in major amputation remained after adjustment. Compared with the South Atlantic region,

Table 3. Factors Associated With Death or Major Amputation After Diagnosis of a Diabetic Foot Ulcer, Identified Using Cox Proportional Hazard Modeling of Amputation-Free Survival

Characteristic	Percentage of Patients Who Survived without a Major Amputation (N = 53 943)	Percentage of Patients Who Died or Underwent Major Amputation (N = 2497)	Unadjusted Hazard Ratio	Multivariate Hazard Ratio (95% CI)	Multivariate P Value
Residing in an HRR with below median infectious disease physician density	26.7	28.0	Ref		
Residing in an HRR with above median infectious disease physician density	73.3	72.0	0.98	0.94 (0.91–0.97)	<.001
Age, year, mean (SD)	77.6 (7.3)	81.1 (7.9)	1.05	1.05 (1.05–1.05)	<.001
Female	61.1	58.4	0.88	0.79 (0.77–0.81)	<.001
Race					
White	82.8	80.5	Ref		
Black	11.9	14.5	1.26	1.27 (1.22–1.32)	<.001
Other	5.4	5.0	0.996	1.03 (0.97–1.10)	.30
Area of residence					
South Atlantic	21.8	21.0	Ref		
Middle Atlantic	19.2	18.7	0.97	0.91 (0.88–0.95)	<.001
East North Central	18.2	18.6	1.04	1.03 (0.99–1.07)	.21
West South Central	10.2	11.8	1.18	1.14 (1.09–1.20)	<.001
Pacific	9.9	8.8	0.93	0.92 (0.87–0.97)	.002
East South Central	5.8	6.4	1.14	1.14 (1.08–1.21)	<.001
West North Central	5.7	6.3	1.11	1.14 (1.07–1.21)	<.001
New England	5.1	5.1	0.99	0.98 (0.92–1.01)	.54
Mountain	4.2	3.4	0.85	0.94 (0.88–1.02)	.13
Urbanicity					
Urban core area	68.6	67.6	Ref		
Large town area	11.3	12.0	1.06	1.11 (1.06–1.16)	<.001
Suburban area	8.4	8.2	1.01	1.06 (1.01–1.11)	.02
Small town/ rural	11.18	11.95	1.06	1.09 (1.05–1.14)	<.001
Ulcer severity					
Early	93.1	89.6	Ref		
Osteomyelitis	4.8	4.4	0.98	1.06 (0.99–1.13)	.08
Gangrene	2.0	6.1	2.62	2.52 (2.34–2.70)	<.001
Uncomplicated diabetes	27.6	26.3	1.11	1.10 (1.06–1.13)	<.001
Prior myocardial infarct	20.1	41.7	1.94	1.73 (1.68–1.77)	<.001
Ischemic heart disease	82.0	92.8	2.12	1.49 (1.42–1.57)	<.001
Prior stroke	31.9	49.8	1.63	1.37 (1.34–1.41)	<.001
History of eye disease	31.8	29.1	0.84	0.89 (0.86–1.14)	<.001
At least 2 visits with their primary care provider in the 2-year baseline period	91.4	90.9	1.02	1.09 (1.04–1.14)	<.001

Abbreviations: CI, confidence interval; HRR, hospital referral region; Ref, reference category; SD, standard deviation.

residents of the Middle Atlantic, East North Central, Pacific, and Mountain regions had lower hazards of major amputation in the main analysis. Those living in the East and West South Central regions had higher hazards of major amputation (Table 2). Urban dwellers had the lowest hazard ratios for major amputation, compared with other urbanicity categories.

DISCUSSION

We found a positive association between access to infectious disease physicians, as measured by their geographic density, and limb preservation for patients with diabetic foot ulcers. This finding suggests that infectious disease physicians may play a beneficial role—direct and/or indirect—in managing diabetic foot ulcers. Multidisciplinary diabetic foot ulcer teams reduce the risk of major amputation, and there is a strong recommendation with moderate-level evidence from IDSA to support their use [13, 31–35]. However, we do not know the optimal constituents of these teams. The IDSA advocates for inclusion or ready access to infectious disease physicians, but there is a low level of evidence to back this recommendation [13, 34, 35]. Our findings support this claim by associating the geographic presence of infectious disease physicians with a reduced risk of

major amputation for patients with diabetic foot ulcers. Our study is also the first to explore the potential role of infectious disease physicians in an ambulatory care sensitive condition. However, the plausibility of a positive impact is substantiated by studies documenting reduced mortality and resource utilization after inpatient infectious disease consultations for a number of different infections, including osteomyelitis [36–38].

We did not find a difference in the impact of infectious disease geographic density on major amputation based on ulcer severity. However, it is possible that none exists when measuring both the direct and indirect effects. Patients with early-stage ulcers may benefit from the direct or indirect input of an infectious disease physician either to avoid the unnecessary use of antibiotics in colonized wounds or to address the skin and soft tissue infections included in this category. The potential for infectious disease physicians to have a direct, positive impact on ulcers complicated by osteomyelitis is likely to be more straightforward, because they have expertise in managing this infection. Benefits in the case of gangrene are also reasonable. Although gangrene is predominantly a surgical issue, the ability to perform a minor amputation with subsequent antibiotic therapy, and thereby avoid a major amputation, often requires input from infectious disease specialists.

After controlling for the density of infectious disease physicians, geographic differences in the risk of major amputation persisted and followed regional trends previously reported [5]. This was expected. Hypotheses for this difference center on variations in medical management and culture [14]. Infectious disease physicians influence both of these facets but are not the sole contributors.

Our study has a number of strengths and is based upon a national sample. Comorbidities, ulcer severity, and major amputation were identified using validated claims algorithms. Infectious disease physician density was calculated using American Medical Association data, rather than relying on Medicare administrative claims specialty codes, which are less sensitive. We found a protective association between infectious disease physician geographic density when modeling both time to major amputation and amputation-free survival. The association was demonstrated in both unadjusted and adjusted analysis, despite increased risk factors for major amputation in the population living in areas with high geographic density of infectious disease physicians.

Our study is limited by the potential for higher geographic densities of infectious disease physicians to be confounded by higher densities of other specialists in the same region. This concern is partially blunted by using HRR as the geographic unit of analysis. All HRRs are defined by tertiary care centers offering specialty care; the range in specialty densities between HRRs should be smaller than if we used hospital service areas, which would not have discriminated between small and large facilities. If we had chosen to assess

the impact of direct infectious disease consultation on major amputation, we would have begun to address the concern for confounding by another specialty. However, unless the effects of all other specialists likely to influence the outcome, eg, vascular surgeons, podiatrists, endocrinologists, wound care specialists, were also included in the model, the potential for confounding would still exist. Furthermore, such a model would only estimate the direct effect of infectious disease specialists, introducing a significant limitation given the substantial amount of informal consulting typically provided by infectious disease physicians [19].

Retrospective, claims-based cohorts are also limited in their ability to provide information on other potential confounders. For instance, the absence of laboratory values precluded adjustment for glycemic control. We attempted to control for socioeconomic factors using the area deprivation index in our sensitivity analysis. However, like all metrics, this index is not complete and leaves room for residual confounding.

CONCLUSIONS

The association between an increased geographic density of infectious disease physicians and a reduction in major amputation suggests that this specialty may play a role in limb salvage. As well as being clinically plausible, direct assessment of multidisciplinary teams containing infectious disease physicians has shown benefit [34, 35]. These lines of evidence support integration of such specialists into multidisciplinary diabetic foot ulcer care to improve limb salvage. Given the magnitude of diabetic foot ulcers, and decreasing enrollment in infectious disease fellowship training, innovative ways to increase access to infectious disease specialists for this population may be needed in the future [39]. Telehealth, recruiting advanced nurse practitioners or physician assistants, and other outreach initiatives may be helpful.

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APPENDIX

International Statistical Classification of Disease and Related Health Problems, Version 9, Codes (ICD-9 codes) Used to Generate Study Variables

Variable	ICD-9 Codes
Diabetic foot ulcer	
Early stage	440.23, 707.1x
Osteomyelitis	730.07, 730.17, 730.27, 730.97
Gangrene	040.0, 440.24 and 785.4 but only if at least one of the following vascular disease codes is also present: 250.7, 440.2, 440.21, 440.22, 440.23
Uncomplicated diabetes	250.00–250.33
Prior myocardial infarction	410.x, 427.4, 427.5
Ischemic heart disease	411.x–414.x, 428.x
Stroke	431.x, 432.0, 432.1, 432.9, 434.x, 436.x
Eye disease	361.9, 379.23, procedure code 14.7