

Association of Wound Healing With Quality and Continuity of Care and Sociodemographic Characteristics

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Chronic wounds, defined as wounds that “fail to proceed through the normal phases of wound healing in an orderly and timely manner,”¹ affect 6.5 million Americans and result in \$50 billion in annual Medicare expenditure.²⁻⁴ Despite growing prevalence and economic burden in the aging US population, chronic wound care remains an area with inconsistent adherence to evidence-based recommendations and variable quality of care.⁵ For example, despite evidence-based recommendations for compression therapy for venous ulcers and total contact casting (TCC) for offloading of pressure for diabetic foot ulcers, a previous study involving 2404 patients from 18 hospital-based outpatient wound care clinics reported that only 17% and 6% of patients received adequate compression and TCC, respectively.⁶ Other studies have similarly documented inconsistent adherence to treating and making diagnoses of chronic wounds, as well as in reporting of wound outcomes across wound care clinics and health systems.⁷⁻¹⁰

Understanding and addressing this variability of care and comparison of outcomes requires a standardized measurement of wound healing outcomes. A commonly used approach to compare institutions is to estimate the rate at which medical events are projected to occur given an institution's case mix and to relate that to the actual observed rate, often called the observed to expected (O/E) ratio. The Agency for Healthcare Research and Quality Inpatient and Patient Safety Indicator Sets use inpatient administrative data to determine whether a hospital had more or fewer events than expected for benchmarking purposes.¹¹ For example, a hospital would have performed better than expected if its expected rate of new pressure ulcers during hospitalization was 1.2% and the actual rate turned out to be 1.0%, resulting in an O/E ratio of 0.83. Conceptually, the O/E ratio reflects a risk-adjusted healing rate but is more intuitive to understand. Lower O/E ratios indicate better-than-expected performance when evaluating negative events, whereas higher O/E ratios indicate better-than-expected performance when evaluating positive outcomes.

In this study, we used a previously developed model to estimate the probability of a chronic wound healing within 12 weeks as a function of patient demographics (eg, age, sex, body mass index,

ABSTRACT

OBJECTIVES: To evaluate the association between clinics' wound healing performance and clinic-level measures of care continuity, clinical quality, and sociodemographic characteristics of the population in their catchment areas.

STUDY DESIGN: In this cross-sectional analysis, we analyzed electronic health records for 180,336 chronic wounds from 480 wound care clinics during the 2018 calendar year.

METHODS: We measured healing performance using a clinic's observed to expected (O/E) ratio, which is based on the rate at which chronic wounds were predicted to heal within 12 weeks given its case mix and the actual healing rate. We compared the top and bottom quintiles, in terms of the O/E ratio, of clinics. Multivariable regression was used to estimate the effect of the clinic-level measures on the O/E ratio.

RESULTS: Clinics in the top quintile had higher rates of care continuity and quality measures, as well as a lower proportion of disadvantaged populations in their catchment areas. In the regression model, 10% increases in a clinic's rate of weekly provider visits, nurse visits, and debridement were associated with 2.5%, 3.0% and 0.7% increases, respectively, in the O/E ratio. The weekly provider visit rate had a greater marginal effect when the proportion of African American residents in the clinic's catchment area was larger.

CONCLUSIONS: Clinic-level measures of care continuity, clinical quality, and sociodemographic composition of their catchment areas' population explain a meaningful part of differences in clinics' wound healing performance. Better care continuity appears to have a greater beneficial effect in disadvantaged populations.

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smoking status), comorbidities (eg, diabetes, heart failure), and wound characteristics (eg, surface area, depth of the lesion, tissue penetration) to estimate the O/E ratios for a large sample of wound care clinics in the United States.¹² Then, we evaluated whether clinic-level factors, such as care continuity, clinical quality, and/or sociodemographic characteristics of the population in their catchment areas, may explain some of the variability noted in the O/E ratios for the healing of chronic wounds. Put differently, we explored which clinic-level factors might explain differences in clinics' case mix-adjusted healing rates.

METHODS

Data

We used electronic health records from a wound care management company's entire network of wound care clinics in 46 states in the United States between January 1 and December 31, 2018. These clinics are staffed by a combination of employed and contracted physicians, who are supported by specialized nurses and case managers. All clinicians are required to attend a 1-week specialty wound care training course and are provided with evidence-based algorithmic clinical practice guidelines. Standardized treatment protocols are in place to promote adherence to evidence-based care. The clinics are hospital based and most have access to specialty consultants and advanced treatment modalities, such as hyperbaric oxygen.

Our original data included 197,302 wounds, for which treatment was started before October 1, 2018, to have a sufficient window for follow-up in 2018, from 518 clinics. We excluded 291 wounds (0.1%) with missing values for the variables in the prediction model and 4307 wounds (2%) with implausible dimensions, such as surface areas greater than 100 cm² for arterial ulcers and 150 cm² for other wound types. We also removed 12,368 wounds (6%) from clinics that had no corresponding sociodemographic data in the US Census Bureau's 2018 American Community Survey 5-year estimates for their zip codes.¹³ The final sample included 180,336 wounds (91%) from 480 wound care clinics. The unit of our analysis was the wound care clinic.

Dependent Variable

The dependent variable for our analysis was the O/E ratio. We used a previously published risk-adjustment model to estimate the expected healing rates for the O/E ratio for each clinic.¹² In short, the logistic regression model predicted whether a wound would heal within 12 weeks from the initial assessment as a function of patient-level demographic and clinical characteristics as well as wound-level characteristics. We recalibrated the model for the current data set, and it achieved an acceptable model fit with an area under the curve of 0.704. For each clinic, observed healing rates were calculated by dividing the number of healed wounds at

TAKEAWAY POINTS

- ▶ Despite the growing prevalence and economic burden of chronic wounds, quality of care for this condition remains inconsistent. Findings from small-scale studies have shown better healing rates with the use of evidence-based care, such as frequent debridement.
- ▶ This study analyzed chronic wounds from 480 clinics to evaluate the association between wound healing performance and continuity and quality of care, as well as sociodemographic factors.
- ▶ Better continuity and quality are associated with better healing performance, after adjusting for sociodemographic characteristics of a clinic's catchment area. Better care continuity appears to have a greater beneficial effect in disadvantaged populations.

the 12-week mark by the number of total wounds. Wounds lost to follow-up were classified as nonhealed in keeping with an intent-to-treat definition for healing rates.¹⁴

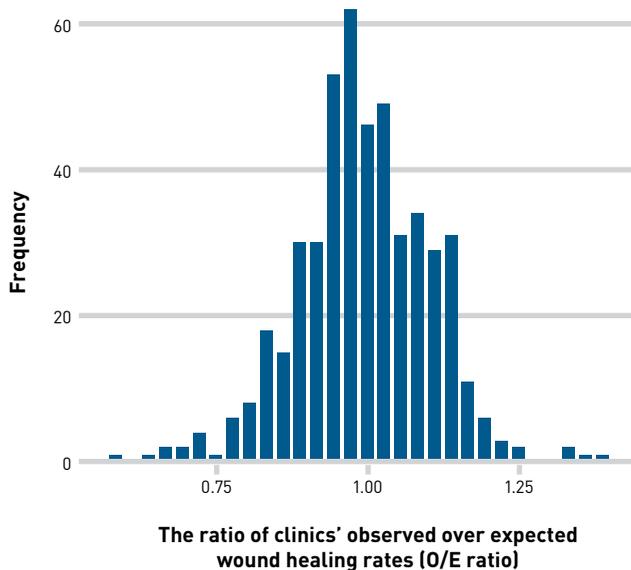
Independent Variables

We combined a review of the published literature and clinical input to identify 3 types of clinic-level factors that may explain the variation in clinics' wound healing performance. These were measures of care continuity, measures of clinical quality, and indicators for the sociodemographic composition of a clinic's catchment area.

As measures of care continuity, we used the clinic-level rates of patients averaging at least 1 visit with a wound care provider each week, as visit frequency has been shown to be associated with healing outcomes.^{15,16} The weekly provider visit rate represents the proportion of patients at a clinic who had at least 1 in-person visit with a clinician during each week of treatment. The calculation of weekly visits did not require each visit to be with the same provider, as many clinics have multiple providers on staff, but each visit had to be at the same clinic to be included. We also used the proportion of visits with a wound care nurse and the clinic's proportion of canceled appointments.

As measures of clinical quality, we selected clinic-level utilization rates of indication-specific treatment modalities. These rates represent the proportion of eligible wounds that received a particular treatment modality, including the use of compression therapy for venous lower leg ulcers, hyperbaric oxygen therapy and TCC for diabetic foot ulcers, and artificial skin substitutes for lower leg wounds that do not show signs of healing after 30 days of treatment. In addition, we used the debridement rate, defined as the proportion of clinic visits during which wounds were debrided, based on evidence that more frequent debridement expedites the healing process and increases healing rates.^{17,18} We also included the number of treated wounds for each clinic as a quality measure because of evidence for a volume-outcome relationship in many clinical areas.

The sociodemographic composition of the population in a clinic's catchment area was approximated using the clinic's zip code. The variables included race/ethnicity, education level, median age, median household income, uninsurance rate, and unemployment rate. Except for median age and household income, all variables represented proportions with numbers between 0 and 1.

FIGURE. Histogram of Wound Care Clinics' Ratio of Observed Over Expected Wound Healing Rates^a

O/E, observed to expected.

^aThe O/E ratio is a clinic's observed healing rate divided by expected healing rate.

Statistical Analysis

For clinic-level descriptive statistics, we calculated the mean value of each variable across all clinics and compared those values in the top and bottom quintiles with respect to the O/E ratio. Throughout this text, we refer to the clinics in the top quintile as “top-performing clinics” and those in the bottom quintile as “bottom-performing clinics.” We compared the mean differences between the top- and bottom-performing clinics on each variable with a *t* test.

We estimated the marginal effect of each independent variable on the O/E ratio using an ordinary least squares linear regression model with robust standard errors for all 480 clinics. We explored the effect of adding interaction terms between variables for care continuity and quality of care with variables for the sociodemographic composition of the catchment area to the linear regression model. These interaction terms capture whether the marginal effect of one variable depends on the level of another variable (ie, whether there are nonlinear effects). For example, the effect of weekly visits could depend on the uninsurance rate of a clinic's catchment area. All statistical analyses were performed using SAS 9.4 (SAS Institute) and R version 3.6.3 (R Foundation for Statistical Computing).

RESULTS

Across all clinics, the mean observed 12-week healing rate was 51%. The O/E ratios ranged between 0.58 and 1.39, with a mean of 0.99 and an SD of 0.11 (Figure). The summary measures of care

continuity, clinical quality, and sociodemographic characteristics of the clinic's catchment area, as well as the comparisons of these variables between the top- and bottom-performing clinics, are presented in Table 1.

Care Continuity

Regarding care continuity, the differences were pronounced between the top- and bottom-performing clinics. The overall rate at which patients averaged weekly provider visits was 36%, and the top-performing clinics had significantly higher rates than the bottom-performing clinics, with an absolute difference of 10 percentage points (41% vs 31%; $P < .01$). The appointment cancellation rate was 11% overall, with bottom-performing clinics having a rate that was an absolute difference of 3 percentage points higher than the top-performing clinics (ie, 13% vs 10%; $P < .01$).

Clinical Quality

In terms of clinical quality, as measured by the utilization rates of indication-specific treatment modalities and clinic volume, the top-performing clinics had directionally higher utilization of all 4 indication-specific treatment modalities and debridement. However, only the differences in the debridement rate and the TCC rate were statistically significant. The mean debridement rate for all clinics was 57%, with top- and bottom-performing clinics having an absolute difference of 9 percentage points (ie, 61% vs 52%; $P < .01$). A total of 42% of eligible wounds received compression therapy and one-third received hyperbaric oxygen therapy, whereas TCC and skin substitutes were rarely used. Overall, the utilization rates for indication-specific treatment modalities were highly variable across clinics, with small and nonsignificant differences between the top- and bottom-performing clinics. For example, the rate of compression therapy had a mean of 42%, an SD of 0.24, a range of 0 to 0.97, and an interquartile range from 0.24 to 0.62.

Sociodemographic Characteristics of a Clinic's Catchment Area

The sociodemographic characteristics of the populations in the clinics' catchment areas showed notable differences between the top- and bottom-performing clinics. The proportion of African Americans was twice as high in the catchment areas of the bottom-performing clinics compared with the top-performing clinics (20% vs 9%; $P < .01$). The populations in the bottom-performing clinics were also characterized by statistically significantly higher unemployment rates (8% vs 6%; $P < .01$) and lower educational attainment, whereas median age, median household income, and uninsurance rate were comparable.

Linear Regression Results

In the multivariable regression model without interaction terms (Table 2), predictors of a higher-than-expected wound healing rate (ie, higher O/E ratio) were higher rates of weekly provider visits, nurse visits, and debridement, as well as higher clinic volume

TABLE 1. Comparison of Care Continuity, Clinical Quality, and Sociodemographic Characteristics of a Catchment Area by Quintiles of O/E Ratio*

Mean (SD)	All clinics (n = 480)	First quintile: bottom-performing (n = 95)	Second quintile (n = 98)	Third quintile (n = 94)	Fourth quintile (n = 95)	Fifth quintile: top-performing (n = 97)	P ^b
Wound healing performance at 12th week							
Observed healing rate	50.7 (0.07)	43.2 (0.06)	48.3 (0.4)	51.2 (0.04)	53.2 (0.04)	57.7 (0.04)	<.01
Expected healing rate	50.8 (0.03)	51.0 (0.03)	51.0 (0.03)	50.9 (0.03)	50.8 (0.03)	50.5 (0.03)	.20
O/E ratio	0.99 (0.11)	0.84 (0.07)	0.94 (0.02)	0.99 (0.01)	1.05 (0.02)	1.14 (0.06)	<.01
Care continuity							
Weekly provider visit	0.36 (0.10)	0.31 (0.11)	0.33 (0.10)	0.36 (0.09)	0.39 (0.09)	0.41 (0.10)	<.01
Nurse visit	0.07 (0.06)	0.06 (0.06)	0.06 (0.05)	0.07 (0.04)	0.07 (0.04)	0.10 (0.07)	<.01
Cancellation	0.11 (0.05)	0.13 (0.05)	0.12 (0.04)	0.11 (0.05)	0.11 (0.04)	0.10 (0.04)	<.01
Clinical quality							
Debridement	0.57 (0.20)	0.52 (0.21)	0.57 (0.20)	0.56 (0.19)	0.60 (0.2)	0.61 (0.17)	<.01
Compression	0.42 (0.24)	0.38 (0.23)	0.40 (0.24)	0.42 (0.24)	0.47 (0.25)	0.44 (0.25)	.08
Skin substitute	0.09 (0.08)	0.08 (0.07)	0.09 (0.07)	0.08 (0.08)	0.09 (0.08)	0.11 (0.09)	.06
Hyperbaric oxygen	0.32 (0.18)	0.32 (0.17)	0.33 (0.19)	0.32 (0.17)	0.29 (0.17)	0.33 (0.18)	.70
Total contact cast	0.06 (0.06)	0.05 (0.05)	0.05 (0.05)	0.06 (0.05)	0.07 (0.05)	0.07 (0.08)	.02
Treated wound count	377 (185)	335 (170)	342 (163)	396 (170)	431 (214)	381 (191)	.08
Sociodemographic characteristics							
Median age	39.5 (6.67)	38.8 (6.71)	39.9 (6.36)	39.5 (5.79)	39.6 (6.87)	39.6 (7.56)	.50
Race and ethnicity (%)							
Non-Hispanic White	0.70 (0.22)	0.58 (0.25)	0.71 (0.20)	0.71 (0.21)	0.74 (0.18)	0.74 (0.20)	<.01
Hispanic	0.11 (0.14)	0.15 (0.18)	0.09 (0.10)	0.12 (0.17)	0.10 (0.11)	0.11 (0.13)	.10
African American	0.13 (0.16)	0.20 (0.22)	0.13 (0.18)	0.11 (0.13)	0.10 (0.12)	0.09 (0.14)	<.01
Other	0.06 (0.06)	0.08 (0.09)	0.06 (0.05)	0.06 (0.05)	0.06 (0.05)	0.06 (0.05)	.12
Unemployment rate	0.07 (0.03)	0.08 (0.04)	0.07 (0.03)	0.06 (0.02)	0.06 (0.02)	0.06 (0.03)	<.01
Median household income (\$)	54,658 (20,744)	52,050 (20,986)	56,610 (23,313)	55,257 (21,181)	55,309 (19,441)	53,442 (17,775)	.62
Uninsurance rate	0.10 (0.05)	0.11 (0.06)	0.10 (0.05)	0.11 (0.06)	0.10 (0.05)	0.10 (0.05)	.08
Education (%)							
Less than high school	0.12 (0.06)	0.13 (0.07)	0.11 (0.06)	0.12 (0.07)	0.11 (0.06)	0.11 (0.06)	.02
High school diploma	0.29 (0.09)	0.28 (0.08)	0.28 (0.08)	0.28 (0.08)	0.30 (0.09)	0.30 (0.09)	.13
Some college	0.30 (0.06)	0.29 (0.06)	0.30 (0.05)	0.30 (0.05)	0.30 (0.05)	0.31 (0.06)	.01
Bachelor's degree or higher	0.30 (0.15)	0.30 (0.16)	0.32 (0.15)	0.30 (0.14)	0.28 (0.14)	0.28 (0.15)	.42

O/E, observed to expected.

*The O/E ratio is a clinic's observed healing rate divided by expected healing rate.

^bT test was used to compare wound care clinics in the top and the bottom quintiles.

and lower appointment cancellation rates: A 10% increase in the weekly provider and nurse visit rates was associated with a 2.5% and 3.0% increase in the O/E ratio, respectively, and a 10% decrease in the cancellation rate with a 2.6% increase in the O/E ratio. Higher debridement rate was also statistically significant and associated with higher O/E ratios, but its effect size was smaller, in that a 10% increase in the debridement rate was associated with a 0.7% increase in the O/E ratio. Additionally, a clinic volume difference of 100 treated wounds was positively associated with a 0.1% change in the O/E ratio. None of the other clinical quality measures were found to be significantly associated with our outcome. The unemployment rate and the proportion of residents in the catchment area with a

bachelor's degree or higher were also significantly associated with lower O/E ratios. This model achieved an R² of 0.30, suggesting that the included variables jointly explain about 30% of the variation in the O/E ratio.

Nonlinear Regression Results

Multiple interaction terms between the sociodemographic characteristics of the catchment area and variables for care continuity and quality were tested. Only the interaction between the proportion of African American residents in a clinic's catchment area and the weekly provider visit rate consistently showed a statistically significant association (Table 2). In this model, the weekly provider

TABLE 2. Marginal Effects of Care Continuity, Clinical Quality, and Sociodemographic Characteristics of a Catchment Area on Clinic’s Healing Performance as Measured by the O/E Ratio^a

		Original model				With interaction term			
		Coef ^b	SE	t	P	Coef ^b	SE	t	P
Continuity	Weekly provider visit	2.5	0.5	4.84	<.01	1.8	0.6	3.14	<.01
	African American*weekly provider visit	Not applicable				4.6	2.3	2.04	.04
	Nurse visit	3.0	1.3	2.36	.02	3.2	1.3	2.52	.01
	Cancellation	-2.6	1.1	-2.31	.02	-2.4	1.1	-2.16	.03
Quality	Debridement	0.7	0.2	3.04	<.01	0.7	0.2	3.12	<.01
	Compression	0.0	0.2	0.14	.89	0.0	0.2	-0.01	.99
	Skin substitute	-0.5	0.7	-0.69	.49	-0.5	0.7	-0.67	.50
	Hyperbaric oxygen	-0.1	0.2	-0.46	.64	-0.1	0.2	-0.58	.56
	Total contact cast	0.9	0.8	1.02	.31	1.0	0.8	1.23	.22
	Wound count ^c	0.1	0.0	5.51	<.01	0.1	0.0	5.13	<.01
	Median age	0.0	0.0	-1.95	.05	0.0	0.0	-1.82	.07
Sociodemographic	Non-Hispanic White	Reference				Reference			
	Hispanic	-0.7	0.6	-1.10	.27	-0.5	0.6	-0.93	.35
	African American	-0.8	0.3	-2.47	.01	-2.2	0.7	-3.26	<.01
	Others	-0.1	0.9	-0.13	.89	-0.1	0.9	-0.13	.90
	Unemployment rate	-4.1	1.9	-2.21	.03	-4.0	1.8	-2.16	.03
	Household income ^d	0.0	0.0	1.09	.28	0.0	0.0	1.03	.31
	Uninsurance rate	-0.8	1.4	-0.60	.55	-1.1	1.4	-0.78	.43
	High school diploma	Reference				Reference			
	Less than high school	-1.8	1.8	-1.00	.32	-2.1	1.8	-1.21	.23
	Some college	-1.1	1.3	-0.84	.40	-1.2	1.3	-0.89	.37
	Bachelor’s degree or higher	-2.4	0.8	-3.13	<.01	-2.5	0.8	-3.22	.01
_constant	1.0	0.1	12.93	<.01	1.1	0.1	13.37	<.01	

Coef, coefficient; O/E, observed to expected; SE, standard error.

^aThe O/E ratio is a clinic’s observed healing rate divided by expected healing rate.

^bCoefficients show the marginal effects of a 10% change in the independent variables on the clinic’s healing performance as measured by the O/E ratio.

^cWound count is in 100s.

^dHousehold income is in \$1000s.

visit rate was associated with a greater marginal effect on the O/E ratio when the proportion of African Americans in a clinic’s catchment area was larger (Table 3). For example, a 10% increase in the weekly provider visit rate was associated with a 2.3% increase in the O/E ratio when 10% of the residents in the catchment area were African American. On the other hand, when 30% of the residents were African American, the same 10% increase in the weekly provider visit rate was associated with a 3.2% increase in the O/E ratio. Other than those 2 variables interacted, all the other variables in this model retained their statistical significance and similar coefficient estimates from the original model.

DISCUSSION

We analyzed the association of a measure of clinics’ risk-adjusted wound healing performance with indicators for care continuity, clinical quality, and the sociodemographic characteristics of their

catchment areas. Using a large sample of 180,336 wounds from 480 clinics, we found that all 3 types of indicators were associated with clinics’ wound healing performance, albeit at different degrees. Our study finds that higher-performing clinics had better continuity of care and clinical quality. Higher-performing clinics also had a lower unemployment rate, higher educational attainment, and a greater proportion of non-Hispanic White individuals in their catchment area. Our findings suggest that, with constant quality and continuity, the sociodemographic composition of the catchment area matters less, and better continuity actually has a greater benefit for clinics serving disadvantaged populations.

Measures of care continuity—the rates of weekly provider and nurse visits and cancellation rates—had the strongest and the most consistent association with the clinic’s performance, with roughly 30% relative differences between the top- and the bottom-performing clinics. In the multivariable regression model, these variables showed statistically significant associations with the O/E ratio and had the largest coefficient sizes after the unemployment rate. Our findings are consistent with those of other studies in wound care and other disease areas, such as hypertension, diabetes, and rheumatoid arthritis, which have demonstrated that higher visit frequency is related to better chronic disease outcomes.^{15,16,19-22}

We also found numerically higher rates of all 5 clinical quality measures in the top-performing wound care clinics, but only the debridement and TCC rates were statistically significantly different from those in the bottom-performing clinics. For the TCC rate, the small absolute difference of only 2 percentage points combined with a low average rate of 5% is unlikely to be clinically meaningful. In the regression model, the volume of wounds treated in a clinic and the debridement rate had statistically significant associations with the O/E ratio, consistent with earlier findings.¹⁷ Although our study did not find a statistically significant association of compression therapy, use of artificial skin substitutes, or hyperbaric oxygen therapy with a clinic’s wound healing performance, this should not be interpreted as evidence for lack of effect of these established treatment modalities.²³⁻²⁷ Rather, the distributions of the usage rates suggest that the modalities are either too infrequently or too variably used to be statistically associated with healing rates.

The sociodemographic characteristics of a population in the clinic’s catchment area showed that the top-performing clinics had a lower unemployment rate, higher educational attainment, and

a greater proportion of non-Hispanic White individuals. However, when adjusting for care continuity and quality, African American race and the unemployment rate had a statistically significant association with the O/E ratio ($P < .05$), whereas the uninsurance rate and median household income did not. These results suggest that comparable continuity and quality of care will result in comparable outcomes, even in disadvantaged populations, which is consistent with findings reported by Hicks et al.²⁸ They analyzed data from a multidisciplinary wound care team and showed that outcomes did not depend on the deprivation index of a patient's residence.

This point is underscored by our finding that the interaction term between the proportion of African American residents in the catchment area and the weekly provider visit rate was significantly positive, implying that the marginal effect of care continuity increased in disadvantaged populations. In other words, those groups appear to benefit disproportionately from care continuity. This result is intuitively plausible, because robust support may matter more in vulnerable groups with fewer resources and lower health literacy. Results confirming similar outcomes for disadvantaged groups, when quality of care is comparable, have been reported for diabetes and heart failure.^{29,30} Such findings point to a path toward improving equity in health care and might have important implications for policy and clinical and managerial decision-making,²⁸ but they are obscured by a large body of research that focuses on quantifying disparities in quality and outcomes.

Limitations

Our study has several limitations. The use of cross-sectional data limits our ability to draw causal inferences, and our findings show only factors associated with a clinic's O/E ratios. Future studies should be based on longitudinal panel data to evaluate how changes in the clinic-level variables are associated with changes in healing performance. Causal interpretation may be achieved with the use of clinic-level fixed effects to control for time invariant unmeasured confounders. We were restricted to routinely collected data, which may have limited the model's explanatory power or even biased estimates. The use of zip codes is an imperfect approximation of a clinic's catchment area. Our measures for quality of care were crude relative to the personalized nature of chronic wound care. In addition, except for the debridement rate, our data captured only whether a particular wound ever received an indication-specific treatment modality, without the documentation of frequency and intensity. This may explain why our study did not find statistically significant association between wound healing performance and the use of each indication-specific treatment modality. Nonetheless, the frequency of debridement, which has robust evidence of a beneficial effect across a wide range of wounds, was associated with higher healing rates. Furthermore, in our analysis, the proportion of African Americans in a clinic's catchment area was correlated with measures of disadvantage, such as lower educational attainment and higher unemployment. Still, it should be viewed as a proxy because disadvantage is a construct that can be operationally

TABLE 3. Variable Marginal Effect of Weekly Provider Visit Rate on Clinic's Healing Performance Over the Proportion of African American Residents in a Clinic's Catchment Area*

Proportion of African American residents in clinic's catchment area	Estimated marginal effect of a 10% increase in the weekly provider visit on clinic's healing performance	95% CI	
		Upper CI	Lower CI
0.1	2.30	3.27	1.33
0.2	2.77	3.77	1.76
0.3	3.23	4.47	1.99
0.4	3.69	5.27	2.12
0.5	4.16	6.13	2.18
0.6	4.62	7.02	2.22
0.7	5.08	7.92	2.25
0.8	5.55	8.83	2.27

*The results show that the estimated effect of weekly provider visit is greater when the proportion of African Americans in a clinic's catchment area is greater. A 10% increase in the weekly provider visit is associated with a 2.30% increase in the clinic's healing performance when the proportion of African American residents in the clinic's catchment area is 10%. When the proportion of African American residents in the clinic's catchment area is 30%, a 10% increase in the weekly provider visit rate is associated with a 3.23% increase in the clinic's healing performance. The weekly provider visit rate represents the proportion of patients at a clinic with at least 1 in-person visit each week.

defined in multiple ways and can encompass other measures such as housing type, access to transportation, household composition, disability, and many more.

CONCLUSIONS

Clinic-level measures of care continuity, clinical quality, and sociodemographic composition of its catchment area's population explain a meaningful part of differences in wound healing performance. Better care continuity appears to have a disproportionately beneficial effect in disadvantaged populations. The cross-sectional results will need to be confirmed with longitudinal data and with the use of more granular indicators for clinical quality. ■

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REFERENCES

- Frykberg RG, Banks J. Challenges in the treatment of chronic wounds. *Adv Wound Care (New Rochelle)*. 2015;4(9):560-582. doi:10.1089/wound.2015.0635
- Fife CE, Carter MJ. Wound care outcomes and associated cost among patients treated in US outpatient wound centers: data from the US Wound Registry. *Wounds*. 2012;24(11):10-17.
- Sen CK, Gordillo GM, Roy S, et al. Human skin wounds: a major and snowballing threat to public health and the economy. *Wound Repair Regen*. 2009;17(6):763-771. doi:10.1111/j.1524-475X.2009.00543.x
- Nussbaum SR, Carter MJ, Fife CE, et al. An economic evaluation of the impact, cost, and Medicare policy implications of chronic nonhealing wounds. *Value Health*. 2018;21(1):27-32. doi:10.1016/j.jval.2017.07.007
- Jones KR, Fennie K, Lenihan A. Evidence-based management of chronic wounds. *Adv Skin Wound Care*. 2007;20(11):591-600. doi:10.1097/01.ASW.0000284936.32707.8d
- Fife CE, Carter MJ, Walker D. Why is it so hard to do the right thing in wound care? *Wound Repair Regen*. 2010;18(2):154-158. doi:10.1111/j.1524-475X.2010.00571.x
- Vowden KR, Vowden P. The prevalence, management and outcome for patients with lower limb ulceration identified in a wound care survey within one English health care district. *J Tissue Viability*. 2009;18(1):13-19. doi:10.1016/j.jtv.2008.11.002
- Wu SC, Jensen JL, Weber AK, Robinson DE, Armstrong DG. Use of pressure offloading devices in diabetic foot ulcers: do we practice what we preach? *Diabetes Care*. 2008;31(11):2118-2119. doi:10.2337/dc08-0771
- Fife CE, Eckert KA, Carter MJ. Publicly reported wound healing rates: the fantasy and the reality. *Adv Wound Care (New Rochelle)*. 2018;7(3):77-94. doi:10.1089/wound.2017.0743
- Srinivasaiah N, Dugdall H, Barrett S, Drew PJ. A point prevalence survey of wounds in north-east England. *J Wound Care*. 2007;16(10):413-416, 418-419. doi:10.12968/jowc.2007.16.10.27910
- Romano P, Hussey P, Ritley D. Selecting quality and resource use measures: a decision guide for community quality collaboratives. Agency for Healthcare Research and Quality. May 2010. Accessed February 15, 2020. <https://www.ahrq.gov/sites/default/files/publications/files/perfmeas.pdf>
- Cho SK, Mattke S, Gordon H, Sheridan M, Ennis W. Development of a model to predict healing of chronic wounds within 12 weeks. *Adv Wound Care (New Rochelle)*. 2020;9(9):516-524. doi:10.1089/wound.2019.1091
- Explore Census data. United States Census Bureau. Accessed February 15, 2020. <https://data.census.gov/cedsci>
- Ennis WJ, Hoffman RA, Gurtner GC, Kirsner RS, Gordon HM. Wound healing outcomes: using big data and a modified intent-to-treat method as a metric for reporting healing rates. *Wound Repair Regen*. 2017;25(4):665-672. doi:10.1111/wrr.12575
- Warriner RA III, Wilcox JR, Carter MJ, Stewart DG. More frequent visits to wound care clinics result in faster times to close diabetic foot and venous leg ulcers. *Adv Skin Wound Care*. 2012;25(11):494-501. doi:10.1097/01.ASW.0000422629.03053.D6
- Carter MJ, Fife CE. Clinic visit frequency in wound care matters: data from the US wound registry. *J Wound Care*. 2017;26(suppl 1):S4-S10. doi:10.12968/jowc.2017.26.Sup1.S4
- Wilcox JR, Carter MJ, Covington S. Frequency of debridements and time to heal: a retrospective cohort study of 312 744 wounds. *JAMA Dermatol*. 2013;149(9):1050-1058. doi:10.1001/jamadermatol.2013.4960
- Steed DL, Donohoe D, Webster MW, Lindsley L. Effect of extensive debridement and treatment on the healing of diabetic foot ulcers. Diabetic Ulcer Study Group. *J Am Coll Surg*. 1996;183(1):61-64.
- Edwards H, Courtney M, Finlayson K, Shuter P, Lindsay E. A randomised controlled trial of a community nursing intervention: improved quality of life and healing for clients with chronic leg ulcers. *J Clin Nurs*. 2009;18(11):1541-1549. doi:10.1111/j.1365-2702.2008.02648.x
- Turchin A, Goldberg SI, Shubina M, Einbinder JS, Conlin PR. Encounter frequency and blood pressure in hypertensive patients with diabetes mellitus. *Hypertension*. 2010;56(1):68-74. doi:10.1161/HYPERTENSIONAHA.109.148791
- Asao K, McEwen LN, Crosson JC, Waitzfelder B, Herman WH. Revisit frequency and its association with quality of care among diabetic patients: Translating Research Into Action for Diabetes (TRIAD). *J Diabetes Complications*. 2014;28(6):811-818. doi:10.1016/j.jdiacomp.2014.06.006
- Ward MM. Rheumatology visit frequency and changes in functional disability and pain in patients with rheumatoid arthritis. *J Rheumatol*. 1997;24(1):35-42.
- Akbari A, Moodi H, Ghiasi F, Sagheb HM, Rashidi H. Effects of vacuum-compression therapy on healing of diabetic foot ulcers: randomized controlled trial. *J Rehabil Res Dev*. 2007;44(5):631-636. doi:10.1682/jrrd.2007.01.0002
- Falanga V, Sabolinski M. A bilayered living skin construct (APLIGRAF) accelerates complete closure of hard-to-heal venous ulcers. *Wound Repair Regen*. 1999;7(4):201-207. doi:10.1046/j.1524-475x.1999.00201.x
- Alvarez OM, Markowitz L, Parker R, Wendelken ME. Faster healing and a lower rate of recurrence of venous ulcers treated with intermittent pneumatic compression: results of a randomized controlled trial. *Eplasty*. 2020;20:e6.
- Marston WA, Hanft J, Norwood P, Pollak R; Dermagraft Diabetic Foot Ulcer Study Group. The efficacy and safety of Dermagraft in improving the healing of chronic diabetic foot ulcers: results of a prospective randomized trial. *Diabetes Care*. 2003;26(6):1701-1705. doi:10.2337/diacare.26.6.1701
- Sanders L, Landsman AS, Landsman A, et al. A prospective, multicenter, randomized, controlled clinical trial comparing a bioengineered skin substitute to a human skin allograft. *Ostomy Wound Manage*. 2014;60(9):26-38.
- Hicks CW, Canner JK, Mathioudakis N, et al. Neighborhood socioeconomic disadvantage is not associated with wound healing in diabetic foot ulcer patients treated in a multidisciplinary setting. *J Surg Res*. 2018;224:102-111. doi:10.1016/j.jss.2017.11.063
- Lanting LC, Joung IMA, Mackenbach JP, Lamberts SWJ, Bootsma AH. Ethnic differences in mortality, end-stage complications, and quality of care among diabetic patients: a review. *Diabetes Care*. 2005;28(9):2280-2288. doi:10.2337/diacare.28.9.2280
- Thomas KL, Hernandez AF, Dai D, et al. Association of race/ethnicity with clinical risk factors, quality of care, and acute outcomes in patients hospitalized with heart failure. *Am Heart J*. 2011;161(4):746-754. doi:10.1016/j.ahj.2011.01.012

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