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Assessing the relationship between community poverty and quality of care for ESRD patients with consideration of case-mix characteristics.

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MPH

Epidemiology

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By

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Bachelor of Arts

Boston University

2009

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An abstract of

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University

in partial fulfillment of the requirements for the degree of
Master of Public Health in Public Health
in Epidemiology

2015

Abstract

Assessing the relationship between community poverty and quality of care
for ESRD patients with consideration of case-mix characteristics.

By Caitlin Casey

Aim To assess the relationship between community poverty and quality of care for ESRD patients with adjustment for relevant case-mix characteristics.

Methods A cross-sectional analysis was conducted using facilities-level data on patients 18-90 years old from ESRD regional surveillance networks and county-level economic data from the national census in the US and its territories from 2005 to 2010. The exposure and outcome studied were community poverty and prevalent AVF use rate. AVF use rates were compared across a gradient of increasing community poverty in the context of case-mix characteristics. Differences in crude AVF prevalence rates and other differences in characteristics of communities and treatment centers were tested using linear regression, ANOVA tests and odds ratio tests of association. Correlations were examined using Pearson's correlation coefficient. Linear regression models were then used to examine the association between the degree of community poverty and the prevalent AVF use rate in the context of case-mix characteristics. The multivariable model with the best fit was selected based on a maximum R^2 statistic and the model with the most variables that significantly contributed to the model with a p-value <0.05.

Results

This study found that there is a statistically strong relationship between county poverty and prevalent AVF rate, such that as county poverty increases, the use of AVF in prevalent cases of ESRD decreases. The final multivariable model indicates that the prevalent AVF rate is not sensitive to county poverty alone, but also to a variety of demographic and clinical case-mix factors, including black ethnicity, diabetic etiology of ESRD and comorbid HTN and CHF. Amputation and unemployment in the patient population were also predictors included in the final multivariable model, although they did not significantly contribute to the model. Although case-mix factors significantly contribute to prevalent rates of AVF use, they do not significantly confound the relationship between county poverty and prevalent AVF use rate.

Conclusions

Increasing AVF use in facilities in indigent areas would both benefit individuals' health outcomes and would help to minimize racial disparities, but improving healthcare access and education in impoverished areas may be equally or more important. Further research would help to achieve better outcomes for poor patients of all demographic and case-mix factors, and appropriately direct intervention efforts. Research should specifically investigate optimal strategies for maximizing AVF use in indigent facilities and in patient populations with high proportions of black patients and clarify when it is appropriate to promote AVF use in ESRD cases with diabetes, CHF and HTN.

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Table of Contents

Introduction

Chronic kidney disease (CKD) is defined as kidney damage or a decreased glomerular filtration rate (GFR) of less than 60 mL/min/1.73m^2 for 3 or more months, regardless of the etiology of damage. As kidney function worsens, patients with CKD develop endocrine and metabolic derangements as well as water and electrolyte disturbances. This leads to protein-energy malnutrition, anemia, bone disease, peripheral and pulmonary edema, hypertension, development or worsening of cardiovascular disease and decreased quality of life. CKD is classified into five stages based on decreasing levels of GFR. Stage 5 CKD represents kidney failure, and is defined as either 1) GFR of less than 15 mL/min/1.73m^2; or 2) survival dependent on dialysis or kidney transplantation[8]. In the United States, 98% of patients initiate dialysis when they reach a GFR of less than 15 mL/min/1.73m^2. End-stage renal disease (ESRD) is a Medicare administrative term that refers to patients treated with dialysis or transplantation[7]. Patients with ESRD or kidney failure have mortality rates up to 13 times higher than the general population, and patients with ESRD have annual death rates of 17-20%[8,13].

CKD is a global public health problem, affecting 200 million people worldwide[8,15]. The increasing economic burden of this disease disproportionately affects low- to middle-income countries, but is unaffordable in developed nations as well. In 2009, ESRD costs in the United States exceeded $40 billion, and although costs to individual patients had increased from previous years, annual costs for hemodialysis patients were three times the treatment costs for those who had undergone transplant[13,15]. In the United States, CKD is the ninth leading cause of death, and the prevalence and incidence of this disease are growing, with 11.5% of adults affected. CKD is associated with age over 60, hypertension (HTN), obesity and cardiovascular disease, as well as black ethnicity[8,11,18]. Because GFR declines with normal aging, CKD is associated with older age: in the US the prevalence and incidence CKD are growing most rapidly in people over 60 and 65, respectively[8,13]. Diabetes and vascular disease are the two most common causes of CKD and largest medical risk factors, with 33% of CKD attributed to diabetic glomerulosclerosis and 21% to vascular disease, most commonly hypertensive nephrosclerosis[8,12] Although the incidence rates of ESRD have stabilized since 2001, risk of ESRD and incidence rate among black Americans is highest, at almost 4 times the incidence rate among whites[13].

Treatment for ESRD consists of delaying or halting CKD progression, treating the disease pathology and providing patients with renal replacement therapy. Delay or control of CKD progression is pursued by treating the underlying cause of the disease and achieving glycemic and blood pressure control. Anemia, endocrine and metabolic derangements are treated with supportive care and by renal replacement therapy with different types of dialysis or kidney transplant[8]. Patients with ESRD require permanent vascular access. Surgically created arteriovenous fistula (AVF) is the preferred procedure for creating vascular access in hemodialysis patients with ESRD. AVF use is preferentially indicated over synthetic bridge grafts, which have higher complication and failure rates and lower survival rates than fistulae [4,6,20].

CKD and ESRD vary greatly in incidence, prevalence, and complication rate across race and ethnicity, socioeconomic gradients and geographic boundaries[14]. Minorities are disproportionately affected by CKD and ESRD, with black persons accelerating to ESRD faster and at a younger age than their white counterparts with similar initial rates of early-stage CKD, even adjusting for higher prevalence of diabetes and hypertension in blacks[18]. Increased risk of ESRD incidence is also associated with neighborhood poverty, for both blacks and whites. However increasing poverty is associated with a widening gap in race-disparate ESRD rates as well, with blacks at higher risk, which indicates that increasing poverty may be a bigger risk factor for blacks and other mortgage-segregated minorities[21].

Substantial variability is also found in treatment of ESRD. Variability in pre-ESRD care among facilities and geographic regions is evident. High variability in pre-ESRD care is associated with increased facility death rates, and facilities with low rates of pre-care and high mortality risk are geographically clustered[10]. Regional practice patterns in vascular access type during hemodialysis also vary greatly[6]. There is substantial evidence that these variations are not based on clinical factors alone. One study found that facility preference influences type of vascular access used despite identical risk of graft failure across facilities, and that preferences for grafts resulted in higher risks of failure[20]. Vascular access type is predicted by clinical case-mix factors, but also by demographic factors independent of clinical case characteristics, including sex, age, race, health care system, socioeconomic status and geographic region[5,6,10,17]. Large socioeconomic and geographic variations in use of preferred practices independent of clinical factors have also been observed in other health services[1,2].

These variations in care and geographic clustering of pre-ESRD healthcare and mortality risk are important because they could contribute to or predict poorer health outcomes independently associated with socioeconomic status and geography. Longer time to transplantation is associated with geographic residence for blacks and whites, with those who live in heavily black neighborhoods experiencing longer wait times. Facilities in geographic locations with more black residents have been shown to have higher-than-expected mortality rates and be less likely to meet other performance standards[19].

Although the exact fundamental causes of health disparities are unknown, many factors probably contribute to them beyond clinical appropriateness and need, including operations within and between health care systems and a variety of institutional and provider biases that may be intentional or not. Infrastructure factors like residential segregation and geographic racial clustering may also contribute to disparities in quality of care and health outcomes[14]. General health services show evidence that community socioeconomic status contributes to health outcomes, with lower community SES predicting poorer dental health[3]. The evidence shows that facilities with low rates of AVF use are geographically clustered and, furthermore, that treatment center AVF use rates among incident ESRD patients are associated with community poverty[10,11].

This study contributes to an existing body of work investigating the degree to which quality ESRD care (facility prevalence rate of AVF) in prevalent ESRD patients is associated with community poverty in the geographic location of the facility[9,11]. Based on a thorough review of the literature, this study tests the hypothesis that facility use of AVF in prevalent cases declines as community poverty increases.

Methods

Study Population

The study population consisted of facilities-level patient populations from ESRD treatment facilities in the United States and its territories. Facilities-level case-mix data on ESRD patients age 18-90 years old from 4,037 facilities across 3,402 zip codes in 56 part of the United States, including 50 states, the District of Colombia, and 5 inhabited territories was used for analysis. Facilities were in one of 18 ESRD regional surveillance networks, which collect patient and facilities data for improvement and prevention of renal disease. Treatment facilities were geocoded to the county where they provided care using US Census data.

Data Source

This study uses ecological data that was taken from the United States ESRD regional surveillance network, consisting of vascular access censuses which provided the total number of prevalent patients and those with a functional AVF, as well as other facilities-level case-mix census information. A total of 4,061 data points were collected for facilities from 2005 to 2010. County poverty for the location of each dialysis facility was categorized using 2010 US Census data.

Measurements

The primary predictor, community poverty, was defined as percent of the facility's local population living below the poverty line (n=3645, nmiss=416). Community poverty data was taken from US Census data after facilities were geocoded to their respective counties. The outcome of interest was rate of AVF use in prevalent cases of ESRD, measured by facility baseline rate of AVF use among prevalent ESRD patients. This data was taken from ESRD surveillance network data.

A priori Confounders

When comparing prevalence rate of AVF across communities with different poverty levels, it might be necessary to adjust for confounding. Based on the review of existing literature, potential confounding was anticipated from facility case-mix factors. Potential confounders were accounted for during statistical analysis using stratified analyses. As previously discussed, prevalence rate of AVF varies with clinical and demographic case-mix factors, such as sex, age and race – perhaps for reasons such as facility preference or provider biases about patients with certain characteristics[2,3,5,6,9,11]. Varying distributions of these characteristics across facilities might affect the prevalence rate of AVF. Conceivably, a facility's patient characteristics may be associated with the socioeconomic status (SES) of the community in which the facility is located. For example, a VA hospital in a rural community may attract a population of veterans and their families, influencing the surrounding community SES. Without evaluation of potential confounders and adjustment for such confounders, quality of care measures may be misleading[16].

Case-mix factors for each facility were taken from de-identified data collected for prevalent patients from the ESRD surveillance network census. Facility case-mix factors include mean age by facility, proportions of prevalent cases by sex as well as proportions of prevalent patients who self-identified their ethnicity as black. Other case-mix factors were also considered as potential confounders including prevalence of diabetes or hypertension as the primary etiology of ESRD and other health status information including history of congestive heart failure, hypertension (HTN), stroke, peripheral vascular disease (PVD), history of amputation, insurance, employment and disability status among ESRD patients. In order to assess the true association between community poverty and quality of care among prevalent ESRD patients, a multivariable model was constructed. The initial model considered all facility-level case-mix factors in addition to intensity of county poverty in predicting quality care. Case-mix factors were subsequently accounted for with stratification as each was assessed for confounding and interaction.

Statistical Analysis

The data were described and analyzed using SAS 9.3. Descriptive statistics for all study variables were calculated as means and proportions using the total study population (n=4,061). Differences in crude AVF prevalence rates and other differences in characteristics of communities and treatment centers were tested using linear regression, ANOVA tests and odds ratio tests of association. Correlations were examined using

Pearson correlation coefficients. Linear regression was then used to examine the association between the degree of community poverty and the prevalent AVF use rate. A multivariable model was constructed considering all covariate contributions to quality of care. The multivariable model with the best fit was selected based on a maximum R^2 statistic and the model with the most variables that significantly contributed to the model with a p-value <0.05.

Results

Of 4,061 observations collected from facilities from 2005 and 2010, there were 416 missing observations for the primary predictor, county poverty level, and 0 missing observations for the outcome of interest, prevalent AVF usage rate. Missing observations were excluded from analysis. The mean (std deviation) for the primary predictor and outcome were 15.18% (5.72) and 0.37(0.14), respectively. When considering the crude association between the exposure of interest and the outcome, there was a statistically strong relationship between community poverty and prevalent AVF rate such that prevalent AVF rate decreased by 0.42853 units for every 1-unit increase in percent of individuals living below the poverty line ($p<0.0001$)(Figure 1). There was a significant contrast between the means of prevalent AVF rate for different poverty ranks by quintile of poverty, with mean prevalent AVF rate trending down as poverty increased ($F=36.03$ and $P<0.0001$)(Figure 2).

Case-mix characteristics were assessed for 3,863 observations, with 198 missing and therefore excluded (Table 1). Averaging data from all facilities, the case mix was approximately 56% male and 33% black, with a mean age of 55. About 63% of patients were insured, and approximately 18-20% were disabled and/or unemployed. On average, cardiovascular disease was the most common comorbidity, with 81% and 37% of the case-mix suffering from hypertension (HTN) and congestive heart failure (CHF) respectively. The primary cause of ESRD was attributed to hypertension in approximately 38% of the case-mix and to diabetes in 22%. Other comorbidities were less common, including peripheral vascular disease (PVD), stroke and history of amputation in approximately 9%, 6% and 1% of the case-mix, respectively.

Most demographic and comorbid case-mix characteristics varied significantly across quartile poverty level (Table 1). Black ethnicity, unemployment and disability increased with severity of poverty while insurance rates, male sex and age decreased ($p_{male}=0.0022$; all others $p<0.0001$). Statistically strong relationships with positive trends between poverty level and comorbid and etiologic hypertension (HTN), indicate that facilities in poorer areas have higher proportions of patients with hypertensive disease ($p<0.0001$; $p=0.0369$). Diabetic etiology of ESRD had a significant, but less straightforwardly positive, trend with increasing poverty, indicating that overall, facilities in different economic areas have different proportions of diabetic patients, but that other factors may contribute significantly to this relationship (p=0.0002). CHF was less prevalent in counties with increasing poverty, likely due to increasing mortality in CHF patients in poorer communities (p<0.0001). The two most rare comorbid conditions, stroke and history of amputation, did not vary significantly across poverty level, and although PVD varied significantly, no clear trend was observed.

Most demographic case-mix characteristics varied significantly across AVF use rate, with the exclusion of age and male sex, which maintained averages of about 55 years of age and 56% across AVF use levels (Table 2). Facility use rates of AVF were lower for populations with higher proportions of black and unemployed patients ($p_{black}<0.0001$; $p_{unemployed}=0.0006$). Prevalence use rates of AVF were higher in facilities with more insured patients (p=0.0014). Disability status varied significantly with prevalent AVF use rate but did not show a clear trend, indicating that overall, AVF rate is different in facilities that have different proportions of disabled patients, but that other factors may contribute significantly to this relationship (p=0.0044). Comorbid case-mix characteristics varied significantly across AVF use rate for patients with CHF and patients with diabetic etiology of ESRD, with AVF used less frequently in facilities with higher proportions of these comorbidities ($p_{CHF}<0.0001$; $p_{diabetic}0.0004$). No other clinically significant trends or statistically significant differences were observed in mean case-mix characteristics across AVF use rate, indicating that there was no simple correlation between other case-mix characteristics and increasing prevalent AVF rate.

The crude odds ratio comparing quality ESRD care (prevalent AVF rate at or above 0.60) with level of county poverty was compared with stratified odds ratios for all potential confounders (Table 3). Before adjusting for age, county poverty was associated with decreasing prevalent AVF use rate (crude OR=0.7883). After stratification, there was evidence of an association between county poverty and prevalent AVF rate that differed by age (OR_H= 1.6 and OR_L=0.7). Like with age, stratified odds ratios differed by more than 10% for all potential confounders, so all were evaluated for heterogeneity using the Breslow-Day test. The Breslow-Day test was positive for the covariates age and history of stroke, however because neither of these case-mix factors was associated with the outcome, there is no indication that age or history of stroke modify the effects of county poverty on prevalent AVF rate (p_{age}=0.0512; p_{cva}=0.001). Because of this, these covariates were not considered effect modifiers and no interaction terms were created for them. All other potential confounders were statistically homogeneous ($p>0.05$). Adjusted odds ratios for all other case-mix factors differed from the crude odds ratio and Cochran-Mantel-Haenszel (CMH) statistics indicated that the association between county poverty and prevalent AVF rate does not remain strong after adjusting for any case-mix factor individually (county poverty and prevalent AVF rate are independent after stratifying on any case-mix factor,) ($p>0.05$ for all CMH).

Case-mix factors were considered confounders if they were associated with the exposure and the outcome (Table 1 and 2); if the OR for the outcome given exposure was homogeneous across their strata (Table 3); and if the pooled OR adjusted for the factor differed from the crude OR estimate (Table 3). The case-mix factors that satisfied these conditions were black ethnicity, insurance, unemployment and disability status, diabetic etiology of ESRD and history of CHF. All six of these terms were included in the full model, along with the other case-mix factors, in order to control for as many potential sources of confounding as possible. Correlations were examined using Pearson correlation coefficients, which were all under 0.60, indicating no substantial correlations between covariates.

A full linear regression model was constructed using the exposure and outcome of interest and the case-mix factors. The full model had Adj R^2=0.0645 with five significantly contributing variables ($p<0.05$)(Table 4). Next, a model was constructed that dropped all nonsignificant covariates from the full model with $p>0.05$, which retained five significant covariates and fit better than the full model (Adj R^2=0.0650). Finally, all possible regressions were evaluated and the model with the best fit was compared with the previously explored models. The final model was selected based on goodness of fit and maximizing the number of covariates with a $p>0.05$. The final model, shown in Table 5, included the exposure of interest as well as the case-mix factors for black ethnicity, diabetic etiology of ESRD, history of CHF, hypertension, amputation and unemployment (Adj R^2=0.0661, MSE=0.12846). Of these covariates, all but amputation and unemployment had a $p<0.05$. (Table 5). Prevalent AVF rate was predicted for the full (Figure 3) and final (Figure 4) models and the regression lines were plotted for the adjusted prevalent AVF rates against county poverty. The equations of the regression lines for the crude AVF rate and the adjusted rates across county poverty were equal. (Figure 5).

Discussion

Comparing the association of potential confounders to different levels of the exposure (poverty level) and outcome of interest (prevalent AVF rate) helped inform which case-mix characteristics should be considered confounders. Trends in Table 1 showing black ethnicity, unemployment and disability increasing with severity of poverty while insurance rates, male sex and age trended inversely most likely reflect predictable institutional biases, residential segregation and geographic racial clustering alluded to in the introduction[18,21]. Trends in Table 2 showed associations between the outcome and black ethnicity, unemployment, disability, and insurance rates that could confound the association between the exposure and outcome. There were no statistical or clinical relationships between prevalent AVF rate and age or male sex. Thus age and male sex could not be considered confounders.

As with age and male sex, Table 1 shows a strong clinical and statistical association between poverty level and comorbid and etiologic hypertension which is likely an extension of the same aforementioned phenomena, reflective of the dearth of education, preventative care and maintenance treatment in neighborhoods that are poor. However, because Table 2 shows no clinical or statistical associations between hypertensive disease and the outcome, these two measures of hypertensive disease were also dismissed as confounders.

As with hypertensive disease, diabetic etiology of ESRD showed a statistically significant, overall positive, relationship with increasing poverty level (Table 1). The inverse relationship of CHF to poverty is the logical outcome of a medical condition with a more severe prognosis than diabetes – CHF prevalence most likely decreases as poverty increases because patients who cannot afford or access maintenance treatment die faster (Table 1).

Proportion of patients with diabetic etiology of ESRD significantly decreased with increasing prevalent rate of AVF, whereas proportion of patients with CHF was clinically and statistically positively associated with prevalent AVF rate. Based on prior studies, which demonstrate that clinical case-mix factors influence AVF rate, this likely reflects competing influences of institutional bias and nature and severity of comorbidity on facility vascular access preferences[5,6,10,17]. Based on the epidemiology of diabetes and

CHF and the review of literature, these apparently contradictory trends most likely reflect consistent phenomena of institutional biases. Black patients are more likely to have both diabetes and CHF. Black patients with diabetes are more likely than white patients to develop nephropathy and black patients with renal disease are more likely to advance to ESRD, and to receive substandard care (low AVF use rate). Black patients with CHF and renal disease are also more likely to advance to ESRD, but because they may die of CHF before their white counterparts with CHF and ESRD, the cohort of white patients with ESRD and CHF that is also more likely to receive standard care may relatively "increase" the prevalent AVF rate. It is possible that CHF serves as a proxy for white ethnicity, but to validate this assertion, more epidemiologic investigation would be required. Regardless, the existing literature overwhelmingly demonstrates the racial disparities of care that underlie and predict poorer health outcomes for patients of color. In this study analysis, because both diabetic etiology of ESRD and CHF were associated with the exposure and outcome, both were considered as potential confounders.

This study found that there is a statistically strong relationship between county poverty and prevalent AVF rate, such that as county poverty increases, the use of AVF in prevalent cases of ESRD decreases. However, the multivariable model indicates that the prevalent AVF rate is not sensitive to county poverty alone, but also to a variety of demographic and clinical case-mix factors. The prevalent AVF rate decreases in response to higher proportions of black patients, a finding consistent with the existing body of literature on ESRD. Prevalent AVF rate also decreases with increasing proportions of patients with diabetic etiology of kidney failure, and increases with increasing proportions of patients with comorbid CHF. Amputation and unemployment in the patient population were also predictors included in the final multivariable model, although they did not significantly contribute to the model. Although case-mix factors significantly contribute to prevalent rates of AVF use, they do not significantly confound the relationship between county poverty and prevalent AVF use rate.

With confounding and effect modifiers accounted for, and adjusted rates controlled for, the equations of the regression lines for the crude AVF rate and the adjusted rates across county poverty were equal, indicating that the relationship between prevalent AVF rate and county poverty is not significantly affected by confounding from demographic and clinical case-mix factors.

This analysis demonstrates that whatever the demographic and case-mix at an institution, community poverty independently predicts whether or not patients receive standard care. Far from dismissing demographic and case-mix as important factors, however, this finding indicates that community poverty, easily assessed using public census data, may be a useful tool in determining how to allocate funding and policy changes to healthcare institutions to prevent substandard care in indigent communities.

Conclusion and Recommendations

CKD is a global public health problem, affecting 200 million people worldwide. It is the ninth leading cause of death in the United States, and costs the US approximately $40 billion annually. Black Americans shoulder about four times the incidence rate as their white counterparts, with higher incidence of ESRD among patients who are elderly and/or have comorbid conditions such as hypertension and diabetes.

Previous literature has demonstrated that ESRD rates vary greatly in incidence, prevalence, and complication rate across race and ethnicity, socioeconomic gradients and geographic boundaries and that vascular access type is predicted by clinical case-mix factors, as well as demographic factors including sex, age, race, socioeconomic status and geographic region. Geographically and economically clustered quality of care is important because these factors could contribute to poorer health outcomes independently associated with socioeconomic status and geography. This study contributes to an existing body of work investigating the degree to which quality ESRD care (facility prevalence rate of AVF) in prevalence patients is associated with community poverty in the geographic location of the facility.

This study found that there is a statistically strong relationship between county poverty and prevalent AVF rate, such that as county poverty increases, the use of AVF in prevalent cases of ESRD decreases. However, the multivariable model indicates that the prevalent AVF rate is not sensitive to county poverty alone, but also to a variety of demographic and clinical case-mix factors. Although case-mix factors significantly contribute to prevalent rates of AVF use, they do not significantly confound the relationship between county poverty and prevalent AVF use rate.

This finding indicates that community poverty, easily assessed using public census data, could help determine how to allocate funding and policy changes to indigent communities to prevent the use of substandard care. Further research should be done to investigate optimal strategies for maximizing AVF use in facilities located in counties with high poverty as well as facilities with high proportions of high-risk demographic factors like black ethnicity. Reducing financial deficits in these institutions, bolstering community preventive care resources or even focusing relief efforts and care improvement campaigns in indigent communities or poor institutions could improve poor health outcomes, and perhaps help close the widening chasm of racial disparity in morbidity and survival of ESRD, and possibly other comorbid diseases such as CHF, diabetes and hypertension. If AVF promotional interventions are directed at facilities in high-poverty areas with heavily black patient populations, important gains may be made in closing the enormous racial disparities in ESRD outcomes. More likely, investments in preventive care programs to increase healthcare access and education would achieve more successful and lasting results, not only in preventing ESRD in poor populations, but in improving community health and infrastructure and in improving or preventing multiple poor health outcomes.

Further research should also be directed at clinical case-mix factors to further clarify when it is appropriate to promote AVF use in ESRD cases with comorbidities such as diabetic etiology, HTN and CHF, in order to further direct AVF promotional interventions to target the appropriate groups.

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Tables and Figures

Table 1.Distribution of potential confounders, alone and ranked by predictor of interest, poverty level (N=3863).

Potential Confounder	All		Mean (Stdev) By Level of Pop % Below Poverty				Equality of Means Test	
	Mean	Std Dev	Level 1	Level 2	Level 3	Level 4	F	Pr>F
Demographic characteristics (%)								
Age (Mean years)	55.08	7.69	56.55 (7.61)	55.24 (7.30)	54.14 (7.32)	54.33 (7.64)	19.18	<0.0001
Male sex	55.98	23.75	57.23 (22.94)	57.19 (23.37)	55.96 (21.96)	53.54 (24.28)	4.88	0.0022
Black ethnicity	33.09	33.77	23.66 (27.91)	25.38 (27.67)	35.11 (32.51)	49.24 (38.41)	117.96	<0.0001
Insured	62.69	26.7	72.64 (23.23)	65.17 (24.50)	58.80 (26.05)	53.99 (26.89)	90.43	<0.0001
Unemployed	19.93	22.63	15.19 (19.05)	17.32 (19.93)	22.55 (22.40)	24.47 (25.57)	34.76	<0.0001
Disabled	18.3	20.46	15.41 (18.76)	17.50 (18.37)	17.65 (18.44)	23.37 (24.24)	25.26	<0.0001
Comorbid characteristics								
Diabetes Primary Cause	21.6	21.73	21.08 (20.42)	21.11 (21.29)	19.93 (19.10)	24.26 (24.06)	6.74	0.0002
HTN Primary Cause	38.44	24.26	36.97 (22.21)	37.64 (23.21)	38.46 (22.76)	40.10 (26.68)	2.83	0.0369
CHF	36.98	25.47	41.42 (24.35)	40.39 (25.37)	35.72 (24.24)	30.41 (25.15)	36.11	<0.0001
HTN	81.74	20.7	80.21 (20.42)	81.15 (20.20)	82.03 (20.20)	84.65 (19.53)	7.91	<0.0001
Stroke	6.07	11.81	6.08 (11.25)	6.05 (12.34)	6.0 (10.27)	6.50 (13.36)	0.34	0.799
PVD	8.81	15.57	8.87 (14.44)	8.44 (14.62)	7.15 (13.21)	10.04 (17.11)	5.68	0.0007
History of Amputation	1.03	4.66	1.05 (5.15)	0.80 (3.73)	0.93 (3.52)	1.15 (4.98)	1.01	0.3886

The distribution of each potential confounder is described for all nonmissing values ("All" column); then by quartile level of poverty, increasing from Level 1 to 4. Means among poverty levels were compared using ANOVA test.

Table 2. Distribution of potential confounders, alone and ranked by quartile level of outcome, prevalent AVF rate (N=3,863).

Potential Confounder	All		Mean (Stdev) By Level of Prevalent AVF Rate				Equality of Means Test	
	Mean	Std Dev	Level 1	Level 2	Level 3	Level 4	F	Pr>F
Demographic characteristics (%)								
Age (Mean years)	55.08	7.69	54.83 (8.18)	54.88 (7.72)	55.25 (7.36)	55.39 (7.48)	1.25	0.291
Male sex	55.98	23.75	55.69 (24.27)	54.90 (23.25)	56.85 (22.99)	56.49 (24.48)	1.3	0.2713
Black ethnicity	33.09	33.77	42.62 (36.05)	35.89 (34.13)	31.45 (32.01)	22.14 (29.18)	65.07	<0.0001
Insured	62.69	26.7	59.94 (25.71)	62.97 (25.99)	63.35 (27.07)	64.54 (26.85)	5.19	0.0014
Unemployed	19.93	22.63	22.08 (24.54)	20.41 (22.12)	19.25 (22.59)	17.94 (20.94)	5.82	0.0006
Disabled	18.3	20.46	19.77 (21.84)	17.39 (19.22)	16.91 (19.36)	19.17 (21.18)	4.38	0.0044
Comorbid characteristics								
Diabetes Primary Cause	21.6	21.73	23.72 (22.80)	21.95 (21.09)	21.10 (21.22)	19.59 (21.61)	6.05	0.0004
HTN Primary Cause	38.44	24.26	39.99 (25.46)	37.37 (22.87)	38.02 (23.96)	38.37 (24.64)	2.05	0.1044
CHF	36.98	25.47	32.67 (25.54)	36.35 (25.20)	38.10 (24.57)	40.88 (25.91)	17.72	<0.0001
HTN	81.74	20.7	81.73 (22.16)	82.74 (19.52)	81.07 (20.88)	81.39 (20.13)	1.19	0.3132
Stroke	6.07	11.81	6.61 (12.24)	5.83 (12.09)	5.95 (11.11)	5.87 (11.77)	0.93	0.4267
PVD	8.81	15.57	9.03 (15.84)	8.88 (15.54)	8.22 (15.12)	9.13 (15.76)	0.67	0.5676
History of Amputation	1.03	4.66	1.06 (4.48)	0.91 (4.14)	0.95 (5.06)	1.20 (5.06)	0.71	0.547

The distribution of each potential confounder is described for all nonmissing values ("All" column, repeated from Table 1); then by quartile level of prevalent AVF rate, increasing from Level 1 to 4. Means among AVF use levels were compared using ANOVA test.

Table 3. Crude and adjusted odds ratios and 95% confidence intervals (CI) according to the predictor and potential confounders to be included in multivariate models.

Variables	OR*	95% CI	Breslow-Day Test for OR Homogeneity		CMH** Adjusted OR Estimate		CMH Statistic	
			Chi-Sq	Pr>Chi-Sq	OR	95% CI	Value	Prob
Poverty***	0.79	(0.55, 1.12)						
Age			3.8024	0.0512	0.85	(0.59,1.22)	0.79	0.37
High	1.61	(0.78, 3.33)						
Low	0.71	(0.47, 1.08)						
Male Sex			0.2322	0.6299	0.86	(0.60,1.24)	0.64	0.42
High	0.73	(0.34,1.59)						
Low	0.91	(0.60, 1.36)						
Black ethnicity			1.6306	0.2016	1.09	(0.75,1.58)	0.19	0.67
High	1.84	(0.75, 4.55)						
Low	0.97	(0.64, 1.47)						
HTN Etiology			0.1053	0.7456	0.85	(0.59, 1.22)	0.78	0.38
High	0.91	(0.51, 1.59)						
Low	0.81	(0.50, 1.30)						
DM Etiology			3.6177	0.0572	0.86	(0.60, 1.24)	0.62	0.43
High	1.43	(0.77, 2.65)						
Low	0.68	(0.43, 1.08)						
CHF			0.7005	0.4026	0.91	(0.64, 1.31)	0.25	0.62
High	1.10	(0.62, 1.95)						
Low	0.81	(0.51, 1.29)						
CVA			10.8486	0.001	0.86	(0.60, 1.23)	0.73	0.39
High	2.27	(1.16, 4.46)						
Low	0.61	(0.40, 0.95)						
HTN			0.5404	0.4623	0.87	(0.61, 1.25)	0.54	0.46
High	1.04	(0.58, 1.84)						
Low	0.78	(0.49,1.26)						
PVD			3.1214	0.0773	0.85	(0.59, 1.22)	0.76	0.38
High	1.31	(0.73, 2.34)						
Low	0.67	(0.42, 1.07)						
Amputation			1.9372	0.164	0.86	(0.60, 1.23)	0.72	0.40
High	1.91	(0.58, 6.34)						
Low	0.80	(0.54, 1.16)						
Disabled			1.2354	0.2664	0.82	(0.57, 1.17)	1.22	0.27

High	0.63	(0.35, 1.14)
Low	0.96	(0.61, 1.51)

Table 3 *Cont.*

Variables	OR*	95% CI	Breslow-Day Test for OR Homogeneity		CMH** Adjusted OR Estimate		CMH Statistic	
Unemployed			0.29	0.5902	0.85	(0.59, 1.22)	0.53	0.47
High	1.03	(0.52, 2.03)						
Low	0.82	(0.53, 1.26)						
Insurance			1.1015	0.2939	0.87	(0.61, 1.26)	0.64	0.43
High	1.27	(0.58, 2.79)						
Low	0.79	(0.53, 1.18)						

*OR: Odds ratio

**CMH: Cochran-Mantel-Haenszel

***Poverty: Exposure of interest, county poverty, representing % individuals below the poverty line

All case-mix characteristics were dichotomized using arbitrary cutpoints to provide groups between which the OR for the exposure and outcome of interest could be compared.

Table 4. Full model predicting prevalent AVF rate

Independent Variable*	Coefficient	Standard Error	T-value	P-value
Poverty	-0.00226	0.00041	-5.47	<0.0001
Age	0.00009	0.00033	0.28	0.7823
Male Sex	-0.00432	0.00952	-0.45	0.65
Black ethnicity	-0.0763	0.00695	-10.97	<0.0001
Diabetic	-0.03443	0.01044	-3.3	<0.0001
CHF	0.01883	0.00925	2.03	0.001
HTN	0.02203	0.01111	1.98	0.0419
Amputation	0.08603	0.04961	1.73	0.0474
Unemployed	-0.01713	0.01002	-1.71	0.0875

*Independent Variable: Variables represent facility-level mean age or percent proportions of respective case-mix characteristics

The full model had 5 significantly contributing variables, with Adjusted R-sq value 0.0645 and root MSE 0.12857.

Table 5. Final model predicting prevalent AVF rate

Independent Variable*	Coefficient	Standard Error	T-value	P-value
Poverty	-0.00218	0.00040	-5.45	<0.0001
Black ethnicity	-0.0763	0.00695	-10.97	<0.0001
Diabetic	-0.03443	0.01044	-3.3	<0.0001
CHF	0.01883	0.00925	2.03	0.001
HTN	0.02203	0.01111	1.98	0.0419
Amputation	0.08603	0.04961	1.73	0.0474
Unemployed	-0.01713	0.01002	-1.71	0.0875

*Independent Variable: Variables represent facility-level mean age or percent proportions of respective case-mix characteristics.

The final model had 5 significantly contributing variables, with Adjusted R-sq value 0.0679 and root MSE 0.12846.

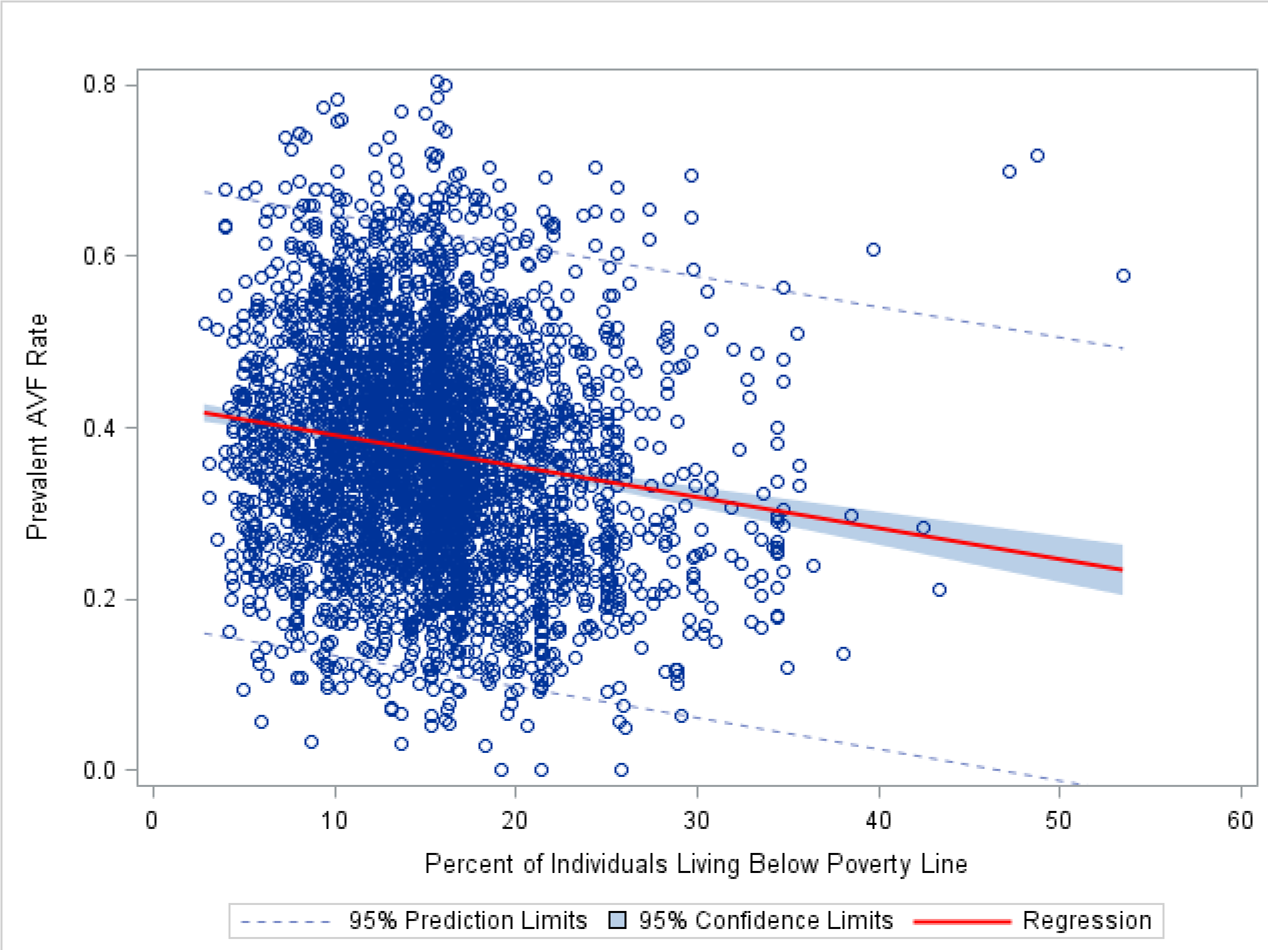

Figure 1. Linear Regression modeling Prevalent AVF Rate as a function of county poverty. The ANOVA procedure for the model produced parameter estimates β_0= 0.42853 and β_1=-0.00366. The corresponding p-values indicate that the intercept and poverty parameter estimates are significant (t=67.63 p<0.0001 and t=-9.30 p<0.0001). From the parameter estimates, the fitted model is
Prevalent AVF Rate=0.42676 + (-0.00362)(Percent below poverty).

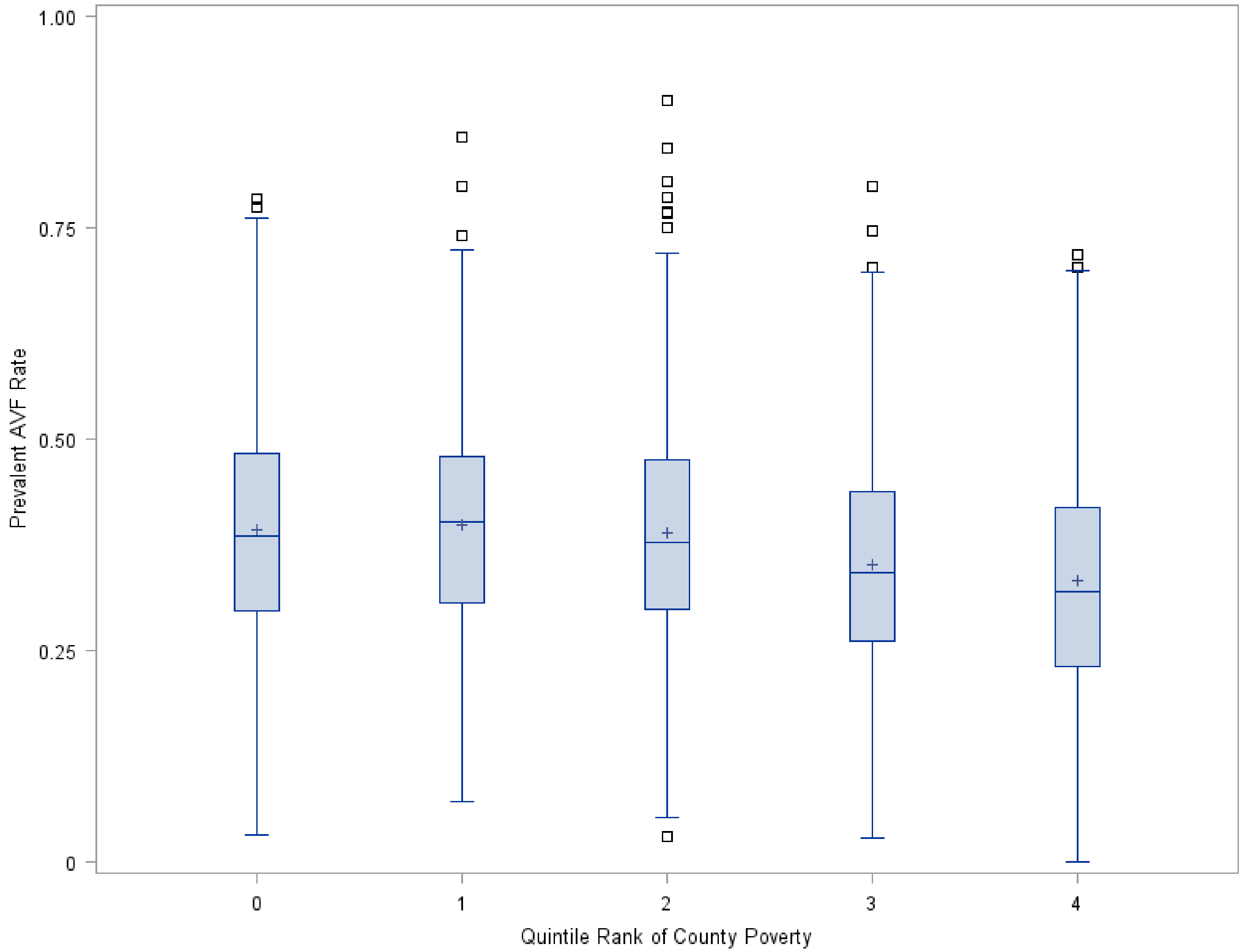

Figure 2. Exploring Prevalent AVF Rate by quintiles of county poverty. The overall F test is significant (the model accounts for a significant portion of the variability in the dependent variable) and the F test for poverty rank is significant (F=36.03 and P<0.0001) (indicating there is a significant contrast between the means for different poverty ranks). The model and poverty rank F tests are identical since poverty rank is the only predictor in the model.

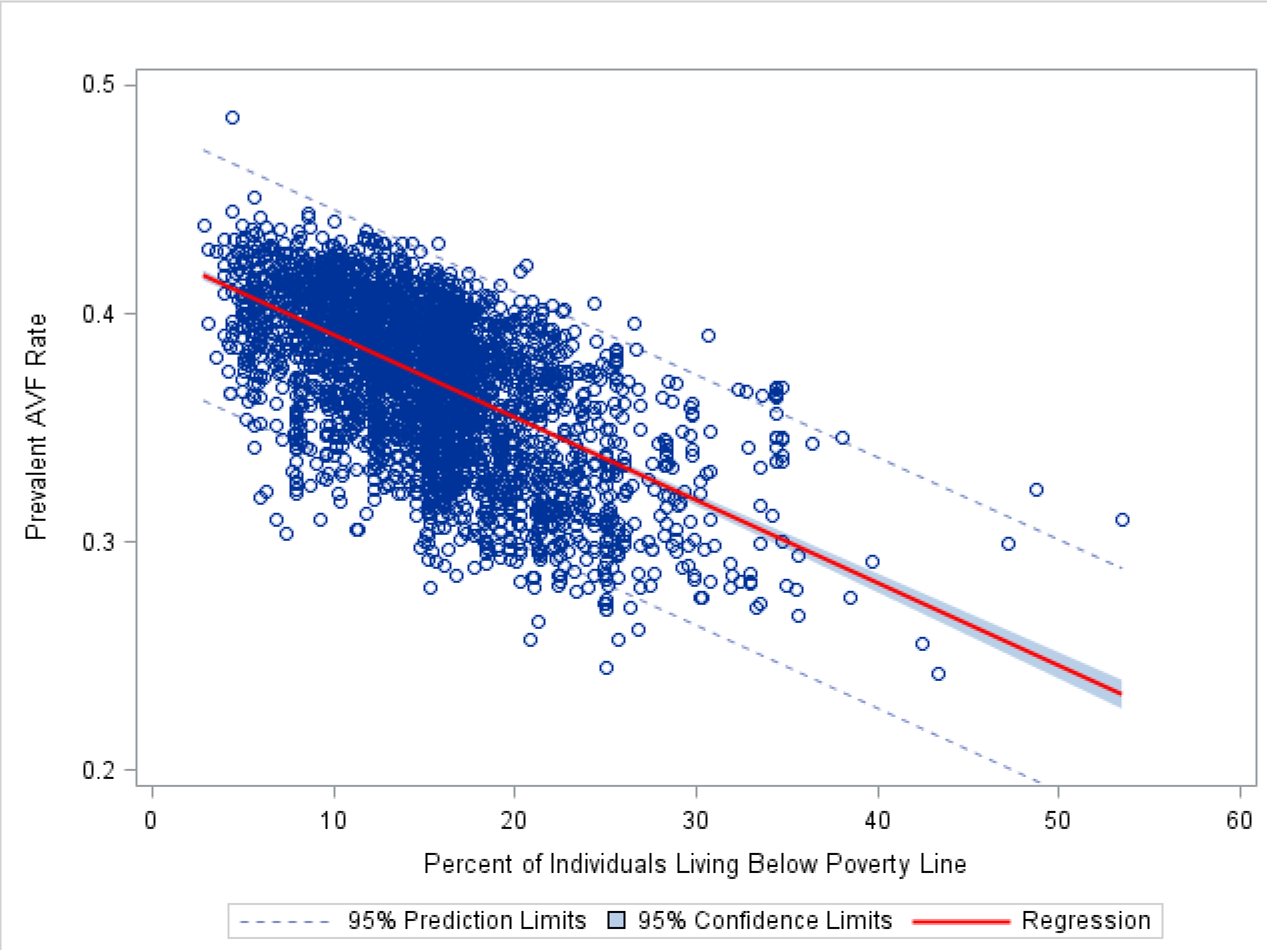

Figure 3. Linear Regression modeling Adjusted Prevalent AVF Rate as a function of county poverty for full model. The ANOVA procedure for the model produced parameter estimates β_0= 0.45719 and β_1=-0.00362. The corresponding p-values indicate that the intercept and poverty parameter estimates are significant (t=317.80 $p<0.0001$ and t=-43.71 $p<0.0001$). From the adjusted parameter estimates, the fitted model is
Prevalent AVF Rate=0.42676 + (-0.00362)(Percent below poverty).

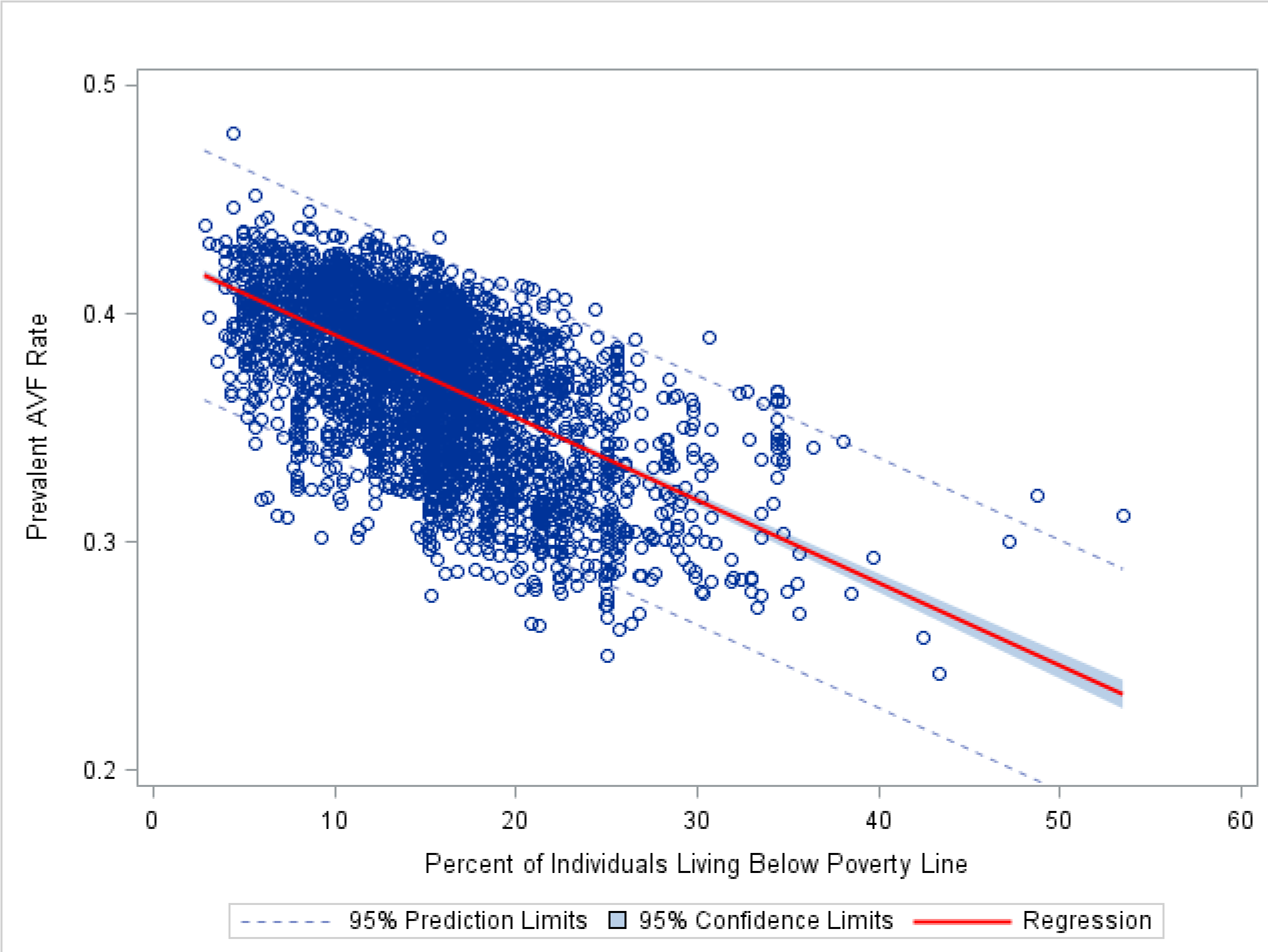

Figure 4. Linear Regression modeling Adjusted Prevalent AVF Rate as a function of county poverty for final model. The adjusted prevalent AVF rate for this model accounted for seven covariates including county poverty, black ethnicity, diabetic etiology of ESRD, history of CHF, HTN, amputation and unemployment. The ANOVA procedure for the model produced parameter estimates β_0= 0.42676 and β_1=-0.00362. The corresponding p-values indicate that the intercept and poverty parameter estimates are significant (t=318.93 p<0.0001 and t=-43.86 p<0.0001). The equation for this model was the same as that for Figure 3.
From the adjusted parameter estimates, the fitted model is
Prevalent AVF Rate=0.42676 + (-0.00362)(Percent below poverty).

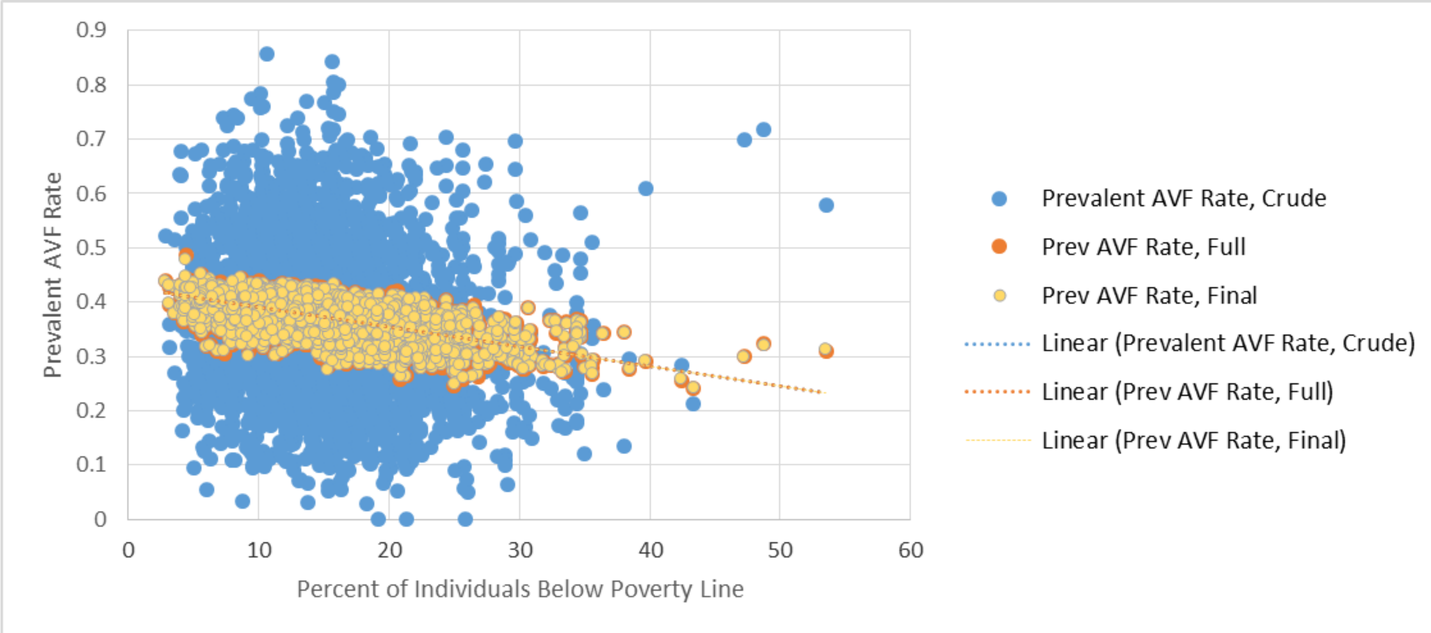

Figure 5. Linear Regression Modeling Prevalent AVF Rate as a Function of County Poverty in Crude, Full and Final Models. The ANOVA procedure for all three models produced parameter estimates β_0= 0.42676 and β_1=-0.00362. Here the crude data are plotted with the adjusted data from the full and final models. The regression line for each series is the same. From the crude or adjusted parameter estimates, the fitted model is Prevalent AVF Rate=0.42676 + (-0.00362)(Percent below poverty).