CHEST Original Research
CRITICAL CARE

Neighborhood Poverty Rate and Mortality in Patients Receiving Critical Care in the Academic Medical Center Setting

Sam Zager, MPhil; Mallika L. Mendu, MD; Domingo Chang, MD; Heidi S. Bazick, MD; Andrea B. Braun, MD; Fiona K. Gibbons, MD; and Kenneth B. Christopher, MD

Background: **Poverty is associated with increased risk of chronic illness but its contribution to critical care outcome is not well defined.**
Methods: **We performed a multicenter observational study of 38,917 patients, aged ≥18 years, who received critical care between 1997 and 2007. The patients were treated in two academic medical centers in Boston, Massachusetts. Data sources included 1990 US census and hospital administrative data. The exposure of interest was neighborhood poverty rate, categorized as <5%, 5% to 10%, 10% to 20%, 20% to 40% and >40%. Neighborhood poverty rate is the percentage of residents below the federal poverty line. Census tracts were used as the geographic units of analysis. Logistic regression examined death by days 30, 90, and 365 post-critical care initiation and in-hospital mortality. Adjusted ORs were estimated by multivariable logistic regression models. Sensitivity analysis was performed for 1-year postdischarge mortality among patients discharged to home.**
Results: **Following multivariable adjustment, neighborhood poverty rate was not associated with all-cause 30-day mortality: 5% to 10% OR, 1.05 (95% CI, 0.98-1.14; *P* = .2); 10% to 20% OR, 0.96 (95% CI, 0.87-1.06; *P* = .5); 20% to 40% OR, 1.08 (95% CI, 0.96-1.22; *P* = .2); >40% OR, 1.20 (95% CI, 0.90-1.60; *P* = .2); referent in each is <5%. Similar nonsignificant associations were noted at 90-day and 365-day mortality post-critical care initiation and in-hospital mortality. Among patients discharged to home, neighborhood poverty rate was not associated with 1-year-postdischarge mortality.**
Conclusions: **Our study suggests that there is no relationship between the neighborhood poverty rate and mortality up to 1 year following critical care at academic medical centers.**

CHEST 2011; 139(6):1368–1379

Abbreviations: BWH = Brigham and Women's Hospital; CPT = current procedural terminology; DRG = diagnosis related group; ICD-9 = *International Classification of Diseases, Ninth Revision*; ICD-9-CM = *International Classification of Diseases, Ninth Revision, Clinical Modification*; MGH = Massachusetts General Hospital; SES = socioeconomic status

Socioeconomic status (SES) is an important determinant of health and mortality.[1,2] An inverse and stepwise relationship between SES and mortality exists.[3-5] Differences in rates of mortality, comorbidities, and disability are closely linked to SES.[1] Those who have an advanced education, have well-paying jobs, and live in neighborhoods with low poverty have a higher life expectancy and lower comorbidities.[1] The mechanism for these observations is unclear. It is postulated that immune-system function may respond to the increased psychosocial stress of low

Manuscript received October 14, 2010; revision accepted February 19, 2011.
Affiliations: From Harvard Medical School (Mr Zager); the Department of Internal Medicine (Dr Mendu) and the Renal Division (Drs Chang, Braun, and Christopher), Brigham and Women's Hospital; and the Department of Anesthesiology (Dr Bazick) and Pulmonary and Critical Care Medicine (Dr Gibbons), Massachusetts General Hospital, Boston, MA.
Funding/Support: This work was supported by the National Institutes of Health [Grant K08AI060881].

Correspondence to: Kenneth B. Christopher, MD, The Nathan E. Hellman Memorial Laboratory, Renal Division, Brigham and Women's Hospital, 75 Francis St, MRB 418, Boston, MA 02115; e-mail: kbchristopher@partners.org

DOI: 10.1378/chest.10-2594

SES environments. Patients with low SES are demonstrated to have increased vulnerability to viral infection.[6-8] SES is also related to immune response to latent viral infection.[9]

Studies on disparities related to critical illness outcomes focus primarily on racial differences and yield conflicting results.[10-16] Although we recognize that race and economic class are intertwined, race is an inherently difficult criterion for classification because of its subjective nature.[17] Given the inconsistency of race-based study results, another variable may be more predictive of outcomes. Longstanding research has shown that race and SES are intertwined, though separate variables meriting independent investigation.[18]

No consensus exists on poverty measurements[19,20] or how to study the interaction of poverty and health.[21] Neighborhood poverty rate, defined as the percentage of the population living below the federal poverty level, is used to describe social inequities in health.[22-24] Neighborhood poverty rate is quantifiable, objective, and well studied.[22,25-29] Area-based socioeconomic measures and health disparity work show that the neighborhood poverty rate can better detect social gradients in numerous health outcomes than can education, wealth, or combination indices.[22]

Prior studies indicate causation between neighborhood poverty rate and health.[30] As reviewed by Krieger and Higgins,[31] independent of individual risk factors, areas with high neighborhood poverty have increased rates of cardiovascular disease,[32] HIV,[33] TB,[34] depression,[35] self-inflicted and interpersonal acts of violence,[36,37] sedentarism,[38-40] and all-cause mortality.[41-43] Additionally, Do and Finch[30] have demonstrated that time-limited exposure to high poverty neighborhoods may have significant health effects.

The few studies that examine economic disparities and mortality in the critically ill are contradictory.[44-46] Given the sparse literature regarding SES and critical care illness outcomes, we sought to elucidate the effect of neighborhood poverty rate (a proxy of SES) on critical care outcomes. The aim of this large, regional, observational, cohort study was to determine if higher neighborhood poverty rates were associated with increased all-cause mortality following initiation of critical care in the academic medical center.

Materials and Methods

Source Population

We extracted administrative and laboratory data from individuals admitted to two academic teaching hospitals in Boston, Massachusetts. Brigham and Women's Hospital (BWH) is a 777-bed teaching hospital with 100 ICU beds. Massachusetts General Hospital (MGH) is a 902-bed teaching hospital with 109 ICU beds. The two hospitals provide primary, as well as tertiary, care to an ethnically and socioeconomically diverse population within eastern Massachusetts and the surrounding region.

Data Sources

Data on all patients admitted to BWH or MGH between November 2, 1997, and December 31, 2007, were obtained through a computerized registry that serves as a central clinical data warehouse for all inpatients and outpatients seen at these hospitals. Approval for the study was granted by the institutional review board of BWH.

The following data were retrieved: demographics, vital status, hospital admission and discharge dates, laboratory values at critical care initiation, diagnosis related group (DRG) assigned at discharge, *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) codes, and current procedural terminology (CPT) codes for in-hospital procedures and services.

Study Population

Between 1997 and 2007, there were 46,208 unique patients, aged ≥ 18 years, assigned the CPT code 99291 (critical care, first 30-74 min) whose address exactly matched the geocode database and who had a DRG assigned following hospital discharge; 5,298 patients whose address geocoded but did not match the 1990 US census file were identified and excluded; 1,712 patients with multiple admissions to the hospital involving critical care (CPT code 99291 assignment) were identified and excluded; 281 patients who were missing one or more laboratory variables were identified and excluded. Thirty-eight thousand, nine hundred seventeen patients constitute the study cohort.

Exposure of Interest and Comorbidities

The exposure of interest was the neighborhood poverty rate, categorized as the percentage of persons below the federal poverty level cutoff. The US Census Bureau uses a set of income thresholds that vary by family size and composition to determine who lives in poverty. The definition of poverty depends on before-tax income but does not include benefits such as public housing, Medicaid, or food stamps. Neighborhood poverty rate is defined as the percentage of people in a small defined area who are below the federal poverty level.[47] Census tracts are small areas (average of 4,000 persons) intended to be homogeneous with respect to economic status and living conditions.[48] Census tracts are common to area-based socioeconomic studies of neighborhood effects on health[49-51] and provide more precise estimates than zip or postal codes.[22,52] In this study, neighborhood poverty rate was stratified a priori into the quintiles < 5%, 5% to 10%, 10% to 20%, 20% to 40%, and 40%, categories based on previous literature.[53-55]

In our cohort, neighborhood poverty rate was determined via submission of patient addresses for geocoding linked to US census data. Geocoding takes advantage of the correlation between neighborhood sociodemographic characteristics and certain characteristics of the residents. Geocoding was performed to the census tract level. The geocoding service matches addresses to latitude/longitude coordinates and then adds census geographic designations to those coordinates, including historic census codes.[56] We used the 1990 decennial US census to obtain the percentage of residents living in poverty per census tract[57] and merged these data with our data set following geocoding. The US census data were obtained from The Public Health Disparities Geocoding Project Monograph.[58]

We used the Deyo-Charlson index to assess the burden of chronic illness. The Deyo-Charlson index consists of 17 comorbidities that are weighted and summed to produce a score each, with an associated weight based on the adjusted risk of 1-year mortality.[59] The Deyo-Charlson index was determined from admission data as well as outpatient visit data prior to patient admission. We employed the *International Classification of Diseases, Ninth Revision* (ICD-9) coding algorithms developed by Quan et al[60] to derive a comorbidity score for each patient. Algorithms developed to recode administrative data into a Deyo-Charlson index are well studied and validated.[61,62]

Sepsis is defined by the presence of any of the following ICD-9-CM codes: 038.0-038.9, 020.0, 790.7, 117.9, 112.5, or 112.81.[63] Acute myocardial infarct is defined by ICD-9-CM 410.0-410.9[64] prior to or on the day of critical care initiation. Number of failed organs was adapted from Martin et al[63] and defined by a combination of ICD-9-CM codes, as outlined in e-Appendix 1. Coronary artery bypass graft surgery performed on the day prior to or after critical care initiation is defined by CPT codes 33510 to 33536. Patient home to hospital distance is calculated as great circle distance from home address to hospital of treatment (MGH or BWH).[65,66] Patient type is defined as medical or surgical and incorporates the DRG methodology, devised by the Centers for Medicare and Medicaid Services.[67] Admission Diagnosis Category is defined as the ICD-9 code given for "reason for admission" and grouped into the ICD-9 Diseases and Tabular Index. Laboratory data were obtained closest to the first hour of the first day of CPT code 99121 assignment.

Assessment of Mortality

Information on vital status for the study cohort was obtained from the Social Security Administration Death Master File. Data from the Social Security Administration Death Master File have a reported sensitivity for mortality up to 92.1% with a specificity of 99.9%, in comparison with >95% with National Death Index, which is the gold standard.[68-71] The administrative database from which our study cohort is derived is updated monthly using the Social Security Administration Death Master File, which itself is updated weekly.[70,72] Use of the Death Master File allows for long-term follow-up of patients following hospital discharge. The censoring date was July 27, 2009.

End Points

The primary end point was 30-day mortality following critical care initiation. Other prespecified end points included 90-day, 365-day, and in-hospital mortality. The 365-day follow-up was attainable for the entire cohort.

Statistical Analysis

Categorical covariates were described by frequency distribution and were compared across exposure groups using contingency tables and χ^2 testing. Continuous covariates were examined graphically and in terms of summary statistics, and compared across exposure groups using one-way analysis of variance. Bivariable associations between covariates (including neighborhood poverty rate) and 30-day mortality were estimated by fitting a series of simple logistic regression models. To allow for the possibility of nonlinear associations, separate models were fit for each continuous covariate in which the variable was alternately specified as a linear and a categorical predictor; fit of these nonnested models was compared by Akaike information criterion, which, in turn, informed specification in multivariable models.

The adjusted association between neighborhood poverty rate and 30-day mortality was estimated by fitting a multivariable logistic regression model, with inclusion of covariate terms thought to interact plausibly with both SES and mortality. Given the robust sample size, no probabilistic selection criteria were applied. Model fit was assessed via the Hosmer-Lemeshow goodness-of-fit test. Additional analyses considering in-hospital, 30-day, 90-day, and 365-day mortality were conducted using an analogous strategy. Number of failed organs was not adjusted for in the primary analysis because it shares ICD-9 codes with the Deyo-Charlson index.

To minimize tertiary referral patterns, we conducted a sensitivity analysis considering in-hospital, 30-day, 90-day, and 365-day mortality in patients who lived within 50 miles of the hospital where they received critical care. Analyses were analogous to the data described here. Additionally, sensitivity analyses were performed for patients with regard to race (white/nonwhite). Finally, hypothesizing that the neighborhood poverty rate might bear a differential association to survival among patients returning to their home environment, we conducted a sensitivity analysis considering 1-year postdischarge survival among patients discharged to home. Survival analyses begin at the date of discharge and continued until the date of death or July 13, 2009. Analyses were otherwise analogous to the data described here, except that additional covariate adjustment was made for length of hospital stay. All *P* values presented are two-tailed; values $<.05$ were considered nominally significant. All analyses were performed using STATA, version 10.0 MP (StataCorp; College Station, Texas).

Validation

Using a similar approach as Krieger et al,[73] 100 street addresses from our cohort were chosen using a true random number service,[74] which we used to validate our cohort-assigned geocodes with those obtained through the US Census Bureau. We used the American Fact Finder section of the US Bureau of the Census Web site, which geocodes to the 1990 census tract level.[75] Each cohort address was evaluated for the presence of the address in the 1990 census and the accuracy of census tract assignment. Cohort addresses that were not present in the 1990 census, and addresses that did not match the assigned census tracts exactly, did not meet the validation criteria.

To ensure the accuracy of postdischarge mortality capture, 100 cohort patients alive at 365 days post-critical care initiation were chosen at random.[74] Because our administrative data set determines death via social security numbers, we queried the Social Security Death Index with other metrics in place of social security numbers to ensure accurate capture of mortality following hospital discharge. The Social Security Death Index was queried by a clinician investigator (A. B. B.) blinded to the exposure of interest and outcome, and date of death if known. Death reported in the Social Security Death Index prior to 365 days post-critical care initiation did not meet the validation criteria.

To validate the accuracy of CPT code 99291 assignment, 100 cohort patient charts were chosen at random.[74] The charts were evaluated for the date of the first CPT code 99291 assignment relative to the date of ICU admission. Charts were sampled and validated by a clinician investigator (A. B. B.) blinded to the exposure of interest, outcome, and date of CPT code 99291 assignment. The reviewer used a structured electronic abstraction form to record (1) critical care initiation date, (2) ED critical care date, (3) ICU admission date, and (4) location of patient prior to ICU admission. The validation criteria were a dated, clinician-derived order for ICU admission or a clinician statement in the medical record noting the date of ICU admission. Critical care performed outside the ICU did not meet the validation criteria.

Results

Of the 38,917 patients studied, 42.4% were women, and 78.7% were white (Table 1). The mean age was 61.7 years (SD, 18.6 years). The majority of patients (89.2%) were from Massachusetts, 4.2% were from

Table 1—*Characteristics of the Study Population (N = 38,917)*

Characteristic	Study Population
Neighborhood poverty rate	
≤ 5%	14,177 (36.8)
5%-10%	12,389 (32.1)
10%-20%	7,297 (18.9)
20%-40%	4,212 (10.9)
> 40%	504 (1.3)
Age, y, mean ± SD	61.7 ± 18.6
Gender	
Female	16,348 (42.4)
Male	22,231 (57.6)
Race	
White	30,359 (78.7)
Black	2,698 (7.0)
Hispanic	2,120 (5.5)
Other	1,550 (4.0)
Unknown	1,852 (4.8)
Patient type	
Medical	20,022 (51.9)
Surgical	18,557 (48.1)
Deyo-Charlson index	
0	4,422 (11.5)
1	6,031 (15.6)
2	7,408 (19.2)
3	6,803 (17.6)
4	5,502 (14.3)
5	3,659 (9.5)
6	2,177 (5.6)
7	1,345 (3.5)
≥ 8	1,232 (3.2)
Home to hospital distance	
≤ 5 miles	13,315 (34.5)
5-25 miles	15,240 (39.5)
25-50 miles	6,784 (17.6)
> 50 miles	3,240 (8.4)
Creatinine	
≤ 0.8 mg/dL	6,624 (17.2)
0.8-1.5 mg/dL	24,408 (63.3)
1.5-3.0 mg/dL	5,295 (13.7)
> 3.0 mg/dL	2,252 (5.84)
BUN	
≤ 20 mg/dL	22,575 (58.5)
20-40 mg/dL	11,053 (28.65)
> 40 mg/dL	4,951 (12.8)
WBC count	
≤ 4×10^3/mm^3	1,219 (3.2)
4-12 $\times 10^3$/mm^3	21,965 (56.9)
> 12×10^3/mm^3	15,395 (39.9)
Hematocrit	
< 30%	7,935 (20.6)
30%-33%	4,941 (12.8)
33%-36%	5,544 (14.4)
36%-39%	6,422 (16.7)
39%-42%	6,110 (15.8)
> 42%	7,627 (19.8)
No. of failed organs	
0	14,101 (36.6)
1	12,588 (32.6)
2	6,882 (17.8)
3	3,159 (8.2)
≥ 4	1,849 (4.8)
Sepsis	4,980 (12.9)
CABG	2,035 (5.3)
AMI	6,081 (15.8)
Admission diagnosis category	
Circulatory	12,009 (31.1)
Injury poisoning	5,793 (15.0)
Unknown	5,691 (14.8)
Ill-defined	5,053 (13.1)
Neoplasms	2,582 (6.7)
Digestive	1,954 (5.1)
Respiratory	1,800 (4.7)
Genitourinary	593 (1.5)
Endocrine	550 (1.4)
Infectious	542 (1.4)
Neurologic	518 (1.3)
Psychiatric	313 (0.8)
Mortality rates	
0-d	5,743 (14.89)
90-d	7,379 (19.13)
365-d	9,894 (25.65)
In-hospital	5,347 (13.86)

Data are presented as No. (%) unless indicated otherwise. AMI = acute myocardial infarct; CABG = coronary artery bypass graft.

New Hampshire, 1.5% were from Rhode Island, and 1.1% were from Maine. Of the cohort patients who live in Massachusetts, the mean neighborhood poverty rate is 10.1% (SD, 9.05%), whereas the mean poverty rate from 1999 to 2007 in all Massachusetts residents is 9.35%.[76,77] Racial demographics for the state of Massachusetts for 2007 show 6.9% blacks, 8.2% Hispanics, and 79.7% white-non Hispanics,[78] as compared with 8.2% blacks, 6.7% Hispanics, and 76.0% white-non Hispanics in cohort subjects residing in Massachusetts.

Table 2 shows the bivariable associations between covariates and neighborhood poverty rate in the cohort. Blacks, Hispanics, younger patients, medical rather than surgical cases, those with hematocrit levels < 36%, and those living ≤ 5 miles from the hospital are all more common in cohort patients with higher neighborhood poverty rates. Additionally, patients with higher neighborhood poverty rates have more acute myocardial infarctions, lower comorbidities (Deyo-Charlson index of 0), and fewer numbers of failed organs. Sepsis does not differ between categories of neighborhood poverty rate.

Multivariable adjusted associations between covariates and 30-day mortality are significant for age, Hispanics, year of admission, patient type (surgical vs medical), Deyo-Charlson index, and values for hematocrit, WBC, serum creatinine, and BUN (Table 3). The association between distance from the hospital and 30-day mortality was not significant. As neighborhood poverty rates increase we observe a significant decrease in gross unadjusted 365-day mortality

Table 2—*Bivariable Associations Between Covariates and Levels of Neighborhood Poverty Rate*

Characteristic	Neighborhood Poverty Rate					*P* Value
	< 5%	5%-10%	10%-20%	20%-40%	> 40%	
No.	14,177	12,389	7,297	4,212	504	…
Age, y, mean ± SD	62.8 ± 17.6	62.7 ± 18.4	61.4 ± 19.4	56.8 ± 19.6	53.3 ± 18.5	< .001
Male gender	8,514 (60.1)	6,982 (56.4)	4,094 (56.1)	2,332 (55.4)	309 (61.3)	< .001
Race						< .001
White	12,617 (89.0)	10,282 (83.0)	5,406 (74.1)	1,889 (44.9)	165 (32.7)	
Black	243 (1.7)	582 (4.7)	762 (10.4)	976 (23.2)	135 (26.8)	
Hispanic	132 (0.9)	434 (3.5)	514 (7.0)	893 (21.2)	147 (29.2)	
Other	472 (3.3)	479 (3.9)	301 (4.1)	263 (6.2)	35 (6.9)	
Unknown	713 (5.0)	612 (4.9)	314 (4.3)	191 (4.5)	22 (4.4)	
Patient type						< .001
Medical	6,468 (45.6)	6,588 (53.2)	4,133 (56.6)	2,503 (59.4)	330 (65.5)	
Surgical	7,709 (54.4)	5,801 (46.8)	3,164 (43.4)	1,709 (40.6)	174 (34.5)	
Deyo-Charlson index						< .001
0	1,471 (10.4)	1,347 (10.9)	901 (12.4)	616 (14.6)	87 (17.3)	
1	2,264 (16.0)	1,870 (15.1)	1,168 (16.0)	661 (15.7)	68 (13.5)	
2	2,840 (20.0)	2,474 (20.0)	1,288 (17.7)	715 (17.0)	91 (18.1)	
3	2,656 (18.7)	2,245 (18.1)	1,174 (16.1)	633 (15.0)	95 (18.9)	
4	2,092 (14.8)	1,759 (14.2)	1,031 (14.1)	556 (13.2)	64 (12.7)	
5	1,329 (9.4)	1,199 (9.7)	712 (9.8)	378 (9.0)	41 (8.1)	
6	749 (5.3)	661 (5.3)	446 (6.1)	297 (7.1)	24 (4.8)	
7	441 (3.1)	428 (3.5)	285 (3.9)	174 (4.1)	17 (3.4)	
≥ 8	335 (2.4)	406 (3.3)	292 (4.0)	182 (4.3)	17 (3.4)	
Creatinine						< .001
≤ 0.8 mg/dL	2,590 (18.3)	2,090 (16.9)	1,130 (15.5)	725 (17.2)	89 (17.7)	
0.8-1.5 mg/dL	8,991 (63.4)	7,886 (63.7)	4,633 (63.5)	2,584 (61.4)	314 (62.3)	
1.5-3.0 mg/dL	1,873 (13.2)	1,686 (13.6)	1,076 (14.8)	595 (14.1)	65 (12.9)	
> 3.0 mg/dL	723 (5.1)	727 (5.9)	458 (6.3)	308 (7.3)	36 (7.1)	
BUN						< .001
≤ 20 mg/dL	8,250 (58.2)	7,151 (57.7)	4,195 (57.5)	2,631 (62.5)	348 (69.1)	
20-40 mg/dL	4,163 (29.3)	3,631 (29.3)	2,104 (28.8)	1,052 (25.0)	103 (20.4)	
> 40 mg/dL	1,764 (12.4)	1,607 (13.0)	998 (13.7)	529 (12.6)	53 (10.5)	
WBC count						< .001
≤ 4 × 10^3/mm^3	482 (3.4)	363 (2.9)	222 (3.0)	131 (3.1)	21 (4.2)	
4-12 × 10^3/mm^3	7,889 (55.7)	7,053 (56.9)	4,230 (58.0)	2,496 (59.3)	297 (58.9)	
> 12 × 10^3/mm^3	5,806 (41.0)	4,973 (40.1)	2,845 (39.0)	1,585 (37.6)	186 (36.9)	
Hematocrit						< .001
< 30%	3,350 (23.6)	2,512 (20.3)	1,291 (17.7)	698 (16.6)	84 (16.7)	
30%-33%	2,034 (14.3)	1,535 (12.4)	850 (11.7)	475 (11.3)	547 (9.3)	
33%-36%	2,170 (15.3)	1,749 (14.1)	1,008 (13.8)	557 (13.2)	60 (11.9)	
36%-39%	2,262 (16.0)	2,088 (16.9)	1,264 (17.3)	724 (17.2)	84 (16.7)	
39%-42%	1,984 (14.0)	1,999 (16.1)	1,240 (17.0)	769 (18.3)	118 (23.4)	
> 42%	2,377 (16.8)	2,506 (20.2)	1,644 (22.5)	989 (23.5)	111 (22.0)	
Home to hospital distance						< .001
≤ 5 miles	860 (6.1)	4,329 (34.9)	4,807 (65.9)	2,991 (71.0)	328 (65.1)	
5-25 miles	8,696 (61.3)	4,694 (37.9)	1,055 (14.5)	679 (16.1)	116 (23.0)	
25-50 miles	3,323 (23.4)	2,170 (17.5)	906 (12.4)	349 (8.3)	36 (7.1)	
> 50 miles	1,298 (9.2)	1,196 (9.7)	529 (7.3)	193 (4.6)	24 (4.8)	
Sepsis	1,898 (13.4)	1,613 (13.0)	916 (12.6)	498 (11.8)	55 (10.9)	.04
CABG	980 (6.9)	639 (5.2)	278 (3.8)	126 (3.0)	12 (2.4)	< .001
AMI	2,071 (14.6)	2,024 (16.3)	1,182 (16.2)	710 (15.9)	94 (18.7)	< .001
No. of failed organs						< .001
0	4,908 (34.3)	4,609 (36.9)	2,868 (39.0)	1,677 (39.4)	209 (41.2)	
1	4,789 (33.5)	4,100 (32.8)	2,340 (31.8)	1,283 (30.1)	161 (31.8)	
2	2,714 (19.0)	2,167 (17.3)	1,235 (16.8)	734 (17.2)	80 (15.8)	
3	1,180 (8.3)	1,046 (8.4)	584 (7.9)	336 (7.9)	32 (6.3)	
4	501 (3.5)	390 (3.1)	230 (3.1)	152 (3.6)	18 (3.6)	
≥ 5	198 (1.4)	183 (1.5)	105 (1.4)	78 (1.8)	7 (1.4)	

(Continued)

Table 2—*Continued*

Characteristic	Neighborhood Poverty Rate <5%	5%-10%	10%-20%	20%-40%	>40%	*P* Value
Admission diagnosis category						<.001
Circulatory	4,837 (34.1)	3,890 (31.4)	2,015 (27.6)	1,134 (26.9)	133 (26.3)	
Injury/poisoning	1,985 (14.0)	1,781 (14.4)	1,150 (15.8)	768 (18.2)	109 (21.6)	
Ill-defined	1,596 (11.3)	1,671 (13.5)	1,091 (15.0)	616 (14.6)	79 (15.7)	
Unknown	1,984 (14.0)	1,952 (15.8)	1,192 (16.3)	521 (12.4)	42 (8.3)	
Neoplasms	1,263 (8.9)	783 (6.3)	346 (4.7)	176 (4.2)	14 (2.8)	
Digestive	678 (4.8)	651 (5.3)	383 (5.3)	217 (5.2)	25 (5.0)	
Respiratory	573 (4.0)	561 (4.5)	382 (5.2)	248 (5.9)	36 (7.1)	
Neurologic	225 (1.6)	158 (1.3)	78 (1.1)	56 (1.3)	5 (1.0)	
Genitourinary	182 (1.3)	177 (1.4)	119 (1.6)	101 (2.4)	14 (2.8)	
Endocrine	153 (1.1)	168 (1.4)	137 (1.9)	81 (1.9)	11 (2.2)	
Infectious	185 (1.3)	164 (1.3)	116 (1.6)	73 (1.7)	4 (0.8)	
Psychiatric	71 (0.5)	85 (0.7)	81 (1.1)	68 (1.6)	8 (1.6)	
Mortality rates, %						
30-d	15.2	15.6	14.1	13.6	13.4	.5
90-d	19.7	20.0	18.2	17.0	15.8	.07
365-d	26.4	26.8	24.5	22.6	20.1	.002
In-hospital	14.2	14.5	12.9	12.8	12.7	.6

Data are presented as No. (%) unless indicated otherwise. See Table 1 for expansion of abbreviations.

rates. Gross unadjusted mortality for the cohort patients with neighborhood poverty rates >60% (n = 40) is as follows: 30 days, 9.8%; 90 days, 14.6%; 365 days, 24.4%; and In-hospital, 15.4%.

Unadjusted models showed a significant dose-response relationship between neighborhood poverty rate and the probability of mortality following critical care initiation. As neighborhood poverty rate increased, there was a decreased odds of 30-day mortality (Table 4). Similar associations were seen with in-hospital, 30-day, and 90-day mortality. Following multivariable adjustment, the association between increased neighborhood poverty rate and all-cause 30-day mortality disappeared. Similarly, after adjustment, nonsignificant associations were noted at 90-day and 365-day mortality post critical care initiation and in-hospital mortality (data not shown). The cohort with the highest neighborhood poverty was younger and had lower comorbidity scores, which likely accounts for the results following adjustment. Sequential multivariable adjustment illustrated that demographics adjustment (specifically age) was primarily responsible for negating the relationship between neighborhood poverty rate and the probability of mortality following critical care (Table 4). The absence of association between neighborhood poverty rate and mortality was not materially modified with additional covariate adjustment for the number of failed organs variable (data not shown).

Sensitivity Analyses

A sensitivity analysis was performed of the effects of excluding patients who live >50 miles from the hospital where they received critical care. Following exclusion of such patients, analysis shows a nonsignificant dose-response relationship between neighborhood poverty rate and the probability of mortality following critical care initiation (Table 5). Sensitivity analysis of 1-year mortality among patients discharged to home shows a nonsignificant dose-response relationship between neighborhood poverty rate and the probability of mortality following critical care initiation (Table 6). Finally, a sensitivity analysis of the effect of race on the association between neighborhood poverty rate and the probability of mortality was performed. Race (white vs nonwhite) does not show a significant effect on the relationship between neighborhood poverty rate and the probability of 30-day mortality following critical care initiation (*P* interaction = .53) (Table 7).

Validation

Upon validation with the American Fact Finder Web site, 98% of addresses and census tracts in our cohort matched. In 98 of the 100 records searched, the street address was found and the 1990 census tract number exactly matched our cohort database (positive predictive value = 98%). In one case in which the street address did not match the census tract number in our cohort, the actual census tract was <0.25 miles away. In another case, we were unable to find the street address with the American Fact Finder Web site.

Validation of postdischarge mortality capture showed no cohort patients who were reported as alive at 365 days post critical care initiation in our data set who were reported dead in the Social Security Death Index. In the 16 cohort patients who died before our censoring date (July 27, 2009) but after

Table 3—*Multivariable Adjusted Associations Between Covariates and 30-d Mortality*

Characteristic	OR	95% CI	*P* Value
Age, per 1 y	1.02	1.01-1.02	.001
Gender			
Male	1	Reference	
Female	1.02	0.95-1.08	.6
Race			
White	1	Reference	
Black	0.83	0.73-0.96	.010
Hispanic	0.74	0.62-0.89	.001
Other	1.32	1.14-1.54	< .001
Unknown	1.42	1.24-1.61	< .001
Patient type			
Medical	1	Reference	
Surgical	0.59	0.55-0.63	< .001
Deyo-Charlson index			
0	1	Reference	
1	2.03	1.67-2.46	< .001
2	2.63	2.18-3.18	< .001
3	3.07	2.54-3.72	< .001
4	3.59	2.96-4.36	< .001
5	3.65	2.99-4.46	< .001
6	3.20	2.58-3.95	< .001
7	3.19	2.54-4.02	< .001
≥ 8	3.18	2.52-4.01	< .001
Creatinine			
< 0.8 mg/dL	1.16	1.06-1.27	.002
0.8-1.5 mg/dL	1	Reference	
1.5-3.0 mg/dL	1.21	1.11- 1.33	< .001
> 3.0 mg/dL	1.16	1.02-1.32	.027
Hematocrit			
< 30%	1.37	1.23-1.52	< .001
30%-33%	1.36	1.22-1.52	< .001
33%-36%	1.22	1.09-1.36	< .001
36%-39%	1.04	0.93-1.16	.5
39%-42%	0.94	0.84-1.05	.3
> 42%	1	Reference	
WBC			
$< 4 \times 10^3/\text{mm}^3$	2.11	1.83-2.43	< .001
$4\text{-}12 \times 10^3/\text{mm}^3$	1	Reference	
$> 12 \times 10^3/\text{mm}^3$	1.80	1.69-1.92	< .001
BUN			
< 20 mg/dL	1	Reference	
20-40 mg/dL	1.47	1.36-1.59	< .001
> 40 mg/dL	2.15	1.92-2.41	< .001
Distance			
< 5 miles	1	Reference	
5-25 miles	1.07	0.98-1.16	.131
25-50 miles	1.15	1.04-1.27	.005
> 50 miles	1.00	0.88-1.14	.982
Sepsis[a]	2.25	2.09-2.43	< .001
AMI[a]	0.94	0.86-1.02	.1
CABG[a]	0.288	0.23-0.35	< .001
Admission diagnosis category			
Circulatory	1	Reference	
Injury/poisoning	1.05	0.93-1.19	.4
Ill-defined[b]	0.72	0.64-0.80	< .001
Neoplasms	1.30	1.15-1.47	< .001
Digestive	0.77	0.67-0.89	< .001
Respiratory	0.98	0.85-1.13	.8
Unknown/other	0.93	0.85-1.01	.09

(Continued)

Table 3—*Continued*

Estimates for each variable are adjusted for all other variables in the table. See Table 1 for expansion of abbreviations.
[a]Referent is absence of condition.
[b]*International Classification of Diseases, Ninth Revision* Diseases and Tabular Index category "Symptoms, Signs and Ill-Defined Conditions."

365 days post critical care initiation, the date of death recovered from the Social Security Death Index via non-social security number metrics exactly matched the date of death in our database.

Validation of CPT 99291 assignment for ICU admission date showed that 87 of the 100 cohort patient records examined with CPT code assignment 99291 were admitted to an ICU (positive predictive value = 87%). In 91% of the 87 cases admitted to an ICU, the date of CPT 99291 was within 24 h of ICU admission. In 96% of the 87 cases, the date of CPT 99291 was within 72 h of ICU admission. Of the 13 patients not admitted to intensive care, 12 received critical care in the ED and were subsequently admitted to the hospital (but not an ICU), and in one patient, no evidence of critical care was found.

Discussion

In this study, we sought to characterize the relationship between neighborhood poverty rate, a proxy for SES, and mortality up to 1 year following critical care. Neighborhood poverty rate meaningfully summarizes important aspects of the neighborhood socioeconomic conditions and consistently detects socioeconomic gradients across a wide range of health outcomes.[22,49,51,79] We used geocoding to identify neighborhood poverty rate, a variable not studied in critical care. We found that there was no difference in 30-day, 90-day, 365-day mortality, and in-hospital mortality following critical care initiation, based on neighborhood poverty rate.

Few studies have examined the association of SES and mortality in critically ill patients. A cohort study of 897 patients in Spain documented an inverse relationship between SES and ICU mortality.[44] Using a composite measure of social deprivation linked to postal code, a study of 716 patients in Scotland found no significant relationship between SES and illness severity, ICU mortality, or length of ICU stay.[45] An Australian study of 15,619 patients demonstrated that in-hospital mortality was not influenced by a postal code-dependent composite measure of SES including educational level, employment status, income, motor vehicle ownership, and fluency in English.[46] However, in the Australian study, a relationship was present between SES and long-term mortality up to

Table 4—*Association Between Neighborhood Poverty Rate and 30-d Mortality With Sequential Multivariable Adjustment*

Neighborhood Poverty Rate	Unadjusted			Model 1[a]			Model 2[b]			Model 3[c]		
	OR	95% CI	*P* Value	OR	95% CI	*P* Value	OR	95% CI	*P* Value	OR	95% CI	*P* Value
5%-10%	1.04	0.97-1.11	.3	1.06	0.98-1.13	.1	1.04	0.96-1.12	.3	1.05	0.98-1.14	.2
10%-20%	0.92	0.85-1.00	.05	0.98	0.90-1.08	.8	0.96	0.88-1.06	.5	0.96	0.87-1.06	.5
20%-40%	0.88	0.80-0.97	.01	1.11	0.99-1.25	.08	1.06	0.94-1.20	.3	1.08	0.96-1.22	.2
> 40%	0.86	0.66-1.12	.3	1.25	0.95-1.64	.1	1.18	0.89-1.56	.3	1.20	0.90-1.60	.2

For each analysis, the referent category is neighborhood poverty rate ≤ 5%. See Table 1 legend for expansion of the abbreviation.
[a]Model 1: adjusted for age, race, gender, year of hospitalization, and distance from hospital.
[b]Model 2: adjusted for age, race, gender, year of hospitalization, distance from hospital, patient type (medical vs surgical), Deyo-Charlson index, sepsis, CABG, and acute myocardial infarct.
[c]Model 3: adjusted for age, race, gender, year of hospitalization, distance from hospital, patient type (medical vs surgical), Deyo-Charlson index, sepsis, CABG, acute myocardial infarct, BUN level, creatinine level, hematocrit level, and WBC count.

6 years. Key to both studies was accounting for greater severity of illness and/or more comorbidity burden among lower SES patients on presentation to the ICU. When that relationship was absent, as in our data, long-term mortality following critical care initiation was not influenced by neighborhood poverty, a proxy for SES.

The limitations of our study stem from its observational design with its inherent biases. The study was performed in a tertiary referral center and thus is limited in its generalizability; the patient population is entirely composed of patients seen at an academic medical center, which may not reflect practices at nonacademic institutions. Per our validation of CPT code 99212, a small proportion of patients in our study received critical care only in the ED and, because of data limitations, we are unable to identify these patients with confidence. We excluded patients who reported no address or homelessness (0.9% of patients) because neighborhood poverty rate is dependent on an address. Although neighborhood of residence independently influences health, it is plausible that mortality is influenced by multiple contexts outside of the patients' own neighborhoods.[32,80] Our study focuses on neighborhood poverty at the time of critical care initiation, which may not reveal fully the contribution of SES to mortality risk.[2] Furthermore, mortality determination in this study is linked to social security number and those patients without a social security number or those not reported as deceased to the Social Security Administration were listed as survivors.[81,82]

The Social Security Administration acknowledges that the Death Master File may contain inaccuracies and does not have a death record for all persons.[72] Postdischarge mortality data obtained from the Social Security Administration Death Master File in our data set may be an imperfect measure of true mortality because of the constraints of the social security number data from which they are constructed. No data exist on the accuracy of the Social Security Administration Death Master File with regard to neighborhood poverty rate. Small sample studies have reported difficulties in ascertaining the mortality status in blacks using national mortality databases.[70,83-85] However, others have reported high sensitivity and moderately reduced sensitivity for black mortality when social security numbers were not used.[86] In our cohort, the percentage of blacks increases with increasing neighborhood poverty. Analysis of cohort patients who expired at discharge (n = 5,355) shows that the Social Security Administration death date and our discharge date match exactly in 98.0% of cases. This group includes 304 black patients, 151 of whom reside in areas with a > 20% neighborhood poverty rate. This would suggest that the Social Security Administration

Table 5—*Sensitivity Analysis of Association Between Neighborhood Poverty Rate and 30-d Mortality Among Patients With Distance From Hospital < 50 Miles*

Neighborhood Poverty Rate	Unadjusted			Adjusted[a]		
	OR	95% CI	*P* Value	OR	95% CI	*P* Value
5%-10%	1.04	0.97-1.11	.3	1.05	0.97-1.13	.2
10%-20%	0.92	0.85-1.00	.05	0.95	0.86-1.06	.4
20%-40%	0.87	0.79-0.96	.008	1.08	0.95-1.23	.3
> 40%	0.85	0.65-1.11	.2	1.19	0.88-1.60	.3

See Table 1 legend for expansion of the abbreviation.
[a]Adjusted for age, gender, race, year of admission, patient type (medical vs surgical), Deyo-Charlson index, sepsis, CABG, acute myocardial infarction, hematocrit level, WBC count, serum creatinine level, and BUN level. For each analysis, the referent category is neighborhood poverty rate ≤ 5%.

Table 6—*Sensitivity Analysis of Association Between Neighborhood Poverty Rate and 1-y Mortality Among Patients Discharged to Home*

	Unadjusted			Adjusted[a]		
Neighborhood Poverty Rate	OR	95% CI	*P* Value	OR	95% CI	*P* Value
5%-10%	0.94	0.83-1.06	.3	0.98	0.86-1.13	.8
10%-20%	0.77	0.67-0.90	.001	0.92	0.77-1.10	.4
20%-40%	0.66	0.54-0.80	.001	0.92	0.73-1.18	.5
>40%	0.85	0.51-1.41	.5	1.25	0.72-2.19	.4

[a]Adjusted for age, gender, race, year of admission, patient type (medical vs surgical), Deyo-Charlson index, sepsis, coronary artery bypass graft, acute myocardial infarction, hematocrit level, WBC count, serum creatinine level, and BUN level. For each analysis, the referent category is neighborhood poverty rate ≤5%.

Death Master File accurately captures death in general in our cohort. Furthermore, we validated postdischarge mortality in our cohort. Despite our observations, mortality status in the Social Security Administration Death Master File may be limited in blacks, which may contribute to the lack of association between mortality and high neighborhood poverty rate in our study.

The social dimensions of neighborhoods contribute to health.[31] It is observed that characteristics of Hispanic communities may offset the negative effects of high neighborhood poverty by the maintenance of favorable health-related behaviors and social support mechanisms.[87] Our cohort has similar numbers of blacks and Hispanics and similar percentages in each neighborhood poverty rate quintile (Table 2). In our cohort patients with a neighborhood poverty rate >20%, gross unadjusted 365-day mortality significantly differs between blacks and Hispanics, 25.4% and 14.6%, respectively ($\chi^2 = 41.92$, $P < .0001$). The outcomes in our cohort of the Hispanic population may have offset the outcomes of blacks with regard to high neighborhood poverty rate.

Our finding that neighborhood poverty is not a significant predictor of mortality does not include physiologic data. In the administrative database used in this study, temperature, BP, heart rate, respiratory rate, Glasgow Coma scale, and APACHE (Acute Physiology and Chronic Health Evaluation) scores are not available. Scoring systems inclusive of physiologic data including APACHE are strong predictors of mortality in critically ill patients.[88] With the addition of age and gender data, the Deyo-Charlson comorbidity index can be considered an alternative method of risk adjustment in the absence of physiologic data.[89] However, despite multivariable adjustment, including an acute organ failure variable, the absence of physiologic data remains a limitation.

The present study has several strengths. Because other chronic medical conditions may affect the attributed cause of death, all-cause mortality is considered an unbiased and clinically relevant outcome in long-term observational studies.[90,91] Our study has sufficient numbers of patients to ensure the adequate reliability of our mortality estimates (n = 38,917, in-hospital mortality rate = 13.9%). In our cohort, CPT codes for critical care had very good agreement with ICU admission. We used previous records prior to admission to define comorbidities, which increases prevalence of these conditions, and results in better risk adjustment.[92,93] Finally, our main variable of interest, neighborhood poverty rate, is studied widely.[22,25-29]

Conclusions

In conclusion, our study suggests that there is no difference in mortality up to 1 year following critical care, based on neighborhood poverty rate, a proxy for SES. Our findings are in contrast to data in other arenas of health care that have established an inverse relationship between SES and mortality.[94-98] We

Table 7—*Sensitivity Analysis of Adjusted Association Between Neighborhood Poverty Rate and 30-d Mortality Among White or Nonwhite Patients*

	Whites			Nonwhites		
Neighborhood Poverty Rate	OR	95% CI	*P* Value	OR	95% CI	*P* Value
5%-10%	1.05	0.97-1.13	.3	1.15	0.99-1.33	.053
10%-20%	1.00	0.90-1.12	.9	0.85	0.71-1.01	.07
20%-40%	1.01	0.86-1.17	.9	1.06	0.88-1.28	.5
>40%	1.00	0.61-1.63	1.0	1.17	0.65-2.11	.6

Race is coded as white or nonwhite. There were 8,220 nonwhite subjects. Adjusted for age, gender, year of admission, patient type (medical vs surgical), Deyo-Charlson index, sepsis, coronary artery bypass graft, acute myocardial infarction, hematocrit level, WBC count, serum creatinine level, and BUN level. For each analysis, the referent category is neighborhood poverty rate ≤5%.

believe the clinical value of our findings is the illustration of neighborhood poverty rate as a poor prognostic marker for mortality up to 1 year following critical illness.

Health disparities based on SES are evident,[99] yet it is possible that not all facets of our health system manifest disparities. Obliterating disparities, therefore, requires that we identify the areas in which they exist, and our study, based at two academic medical centers, suggests that critical care may not be one of those areas. Because prehospital factors exert such a consistent force on outcomes, with poorer people presenting younger and sicker, resources and efforts aimed at reducing socioeconomic disparities might best be directed toward primary care and prevention of illness prior to critical care initiation.

Acknowledgments

Author contributions: Dr Christopher is the guarantor of the study and takes responsibility for the integrity of the work as a whole, from inception to published article.
Mr Zager: contributed to project design and manuscript preparation.
Dr Mendu: contributed to project design and manuscript preparation.
Dr Chang: contributed to database generation and review of the manuscript.
Dr Bazick: contributed to database generation and review of the manuscript.
Dr Braun: contributed to verification of CPT coding, verification of death following hospital discharge, and review of the manuscript.
Dr Gibbons: contributed to manuscript preparation.
Dr Christopher: contributed to project design, manuscript preparation, database generation, verification of geocode data, and statistical analysis oversight.
Financial/nonfinancial disclosures: The authors have reported to *CHEST* that no potential conflicts of interest exist with any companies/organizations whose products or services may be discussed in this article.
Role of sponsors: The sponsor had no role in the design of the study, the collection and analysis of the data, or in the preparation of the manuscript.
Other contributions: This manuscript is dedicated to the memory of our dear friends and colleagues Keith Alan Landesman, MD, and Nathan Edward Hellman, MD, PhD. We express deep appreciation to John Ayanian, MD, for constructive criticism and Steven M. Brunelli, MD, MSCE, for statistical expertise and analysis.
Additional information: The e-Appendix can be found in the Online Supplement at http://chestjournal.chestpubs.org/content/139/6/1368/suppl/DC1.

References

1. Isaacs SL, Schroeder SA. Class-the ignored determinant of the nation's health. *N Engl J Med*. 2004;351(11):1137-1142.
2. Smith GD, Hart C, Blane D, Gillis C, Hawthorne V. Lifetime socioeconomic position and mortality: prospective observational study. *BMJ*. 1997;314(7080):547-552.
3. Adler NE, Boyce WT, Chesney MA, Folkman S, Syme SL. Socioeconomic inequalities in health. No easy solution. *JAMA*. 1993;269(24):3140-3145.
4. Adler NE, Newman K. Socioeconomic disparities in health: pathways and policies. *Health Aff (Millwood)*. 2002;21(2):60-76.
5. Guralnik JM, Land KC, Blazer D, Fillenbaum GG, Branch LG. Educational status and active life expectancy among older blacks and whites. *N Engl J Med*. 1993;329(2):110-116.
6. Zorrilla EP, Luborsky L, McKay JR, et al. The relationship of depression and stressors to immunological assays: a meta-analytic review. *Brain Behav Immun*. 2001;15(3):199-226.
7. Cohen S, Tyrrell DA, Smith AP. Psychological stress and susceptibility to the common cold. *N Engl J Med*. 1991;325(9):606-612.
8. Cohen S, Doyle WJ, Skoner DP, Rabin BS, Gwaltney JM Jr. Social ties and susceptibility to the common cold. *JAMA*. 1997;277(24):1940-1944.
9. Dowd JB, Haan MN, Blythe L, Moore K, Aiello AE. Socioeconomic gradients in immune response to latent infection. *Am J Epidemiol*. 2008;167(1):112-120.
10. Erickson SE, Shlipak MG, Martin GS, et al; National Institutes of Health National Heart, Lung, and Blood Institute Acute Respiratory Distress Syndrome Network. Racial and ethnic disparities in mortality from acute lung injury. *Crit Care Med*. 2009;37(1):1-6.
11. Palmeri ST, Lowe AM, Sleeper LA, Saucedo JF, Desvigne-Nickens P, Hochman JS; SHOCK Investigators. Racial and ethnic differences in the treatment and outcome of cardiogenic shock following acute myocardial infarction. *Am J Cardiol*. 2005;96(8):1042-1049.
12. Foreman MG, Willsie SK. Health care disparities in critical illness. *Clin Chest Med*. 2006;27(3):473-486, vii.
13. Spertus J, Safley D, Garg M, Jones P, Peterson ED. The influence of race on health status outcomes one year after an acute coronary syndrome. *J Am Coll Cardiol*. 2005;46(10):1838-1844.
14. Esper AM, Moss M, Lewis CA, Nisbet R, Mannino DM, Martin GS. The role of infection and comorbidity: Factors that influence disparities in sepsis. *Crit Care Med*. 2006;34(10):2576-2582.
15. Phillips RS, Hamel MB, Teno JM, et al; The SUPPORT Investigators. Race, resource use, and survival in seriously ill hospitalized adults. *J Gen Intern Med*. 1996;11(7):387-396.
16. Williams JF, Zimmerman JE, Wagner DP, Hawkins M, Knaus WA. African-American and white patients admitted to the intensive care unit: is there a difference in therapy and outcome? *Crit Care Med*. 1995;23(4):626-636.
17. Marmot M. Health in an unequal world: social circumstances, biology and disease. *Clin Med*. 2006;6(6):559-572.
18. Horner RD, Lawler FH, Hainer BL. Relationship between patient race and survival following admission to intensive care among patients of primary care physicians. *Health Serv Res*. 1991;26(4):531-542.
19. Betson D, Warlick JL. Measuring poverty. In: Oakes J, Kaufman, JS, eds. *Methods in Social Epidemiology*. San Francisco, CA: Jossey-Bass; 2006:108-129.
20. Citro C, Michael, RT, eds. *Measuring Poverty: A New Approach*. Washington, DC: National Academy Press; 1995.
21. Aber JL, Bennett NG, Conley DC, Li J. The effects of poverty on child health and development. *Annu Rev Public Health*. 1997;18:463-483.
22. Krieger N, Chen JT, Waterman PD, Soobader MJ, Subramanian SV, Carson R. Geocoding and monitoring of US socioeconomic inequalities in mortality and cancer incidence: does the choice of area-based measure and geographic level matter?: the Public Health Disparities Geocoding Project. *Am J Epidemiol*. 2002;156(5):471-482.
23. Krieger N, Chen JT, Waterman PD, Rehkopf DH, Subramanian SV. Painting a truer picture of US socioeconomic and racial/ethnic health inequalities: the Public

Health Disparities Geocoding Project. *Am J Public Health*. 2005;95(2):312-323.
24. Nandi A, Glass TA, Cole SR, et al. Neighborhood poverty and injection cessation in a sample of injection drug users. *Am J Epidemiol*. 2010;171(4):391-398.
25. Cunradi CB, Caetano R, Clark C, Schafer J. Neighborhood poverty as a predictor of intimate partner violence among White, Black, and Hispanic couples in the United States: a multilevel analysis. *Ann Epidemiol*. 2000;10(5):297-308.
26. Polednak AP. Stage at diagnosis of prostate cancer in Connecticut by poverty and race. *Ethn Dis*. 1997;7(3):215-220.
27. Ensminger ME, Lamkin RP, Jacobson N. School leaving: a longitudinal perspective including neighborhood effects. *Child Dev*. 1996;67(5):2400-2416.
28. McWhorter WP, Schatzkin AG, Horm JW, Brown CC. Contribution of socioeconomic status to black/white differences in cancer incidence. *Cancer*. 1989;63(5):982-987.
29. Breen N, Figueroa JB. Stage of breast and cervical cancer diagnosis in disadvantaged neighborhoods: a prevention policy perspective. *Am J Prev Med*. 1996;12(5):319-326.
30. Do DP, Finch BK. The link between neighborhood poverty and health: context or composition? *Am J Epidemiol*. 2008;168(6):611-619.
31. Krieger J, Higgins DL. Housing and health: time again for public health action. *Am J Public Health*. 2002;92(5):758-768.
32. Diez Roux AV, Merkin SS, Arnett D, et al. Neighborhood of residence and incidence of coronary heart disease. *N Engl J Med*. 2001;345(2):99-106.
33. Wallace R. A synergism of plagues: "planned shrinkage," contagious housing destruction, and AIDS in the Bronx. *Environ Res*. 1988;47(1):1-33.
34. Barr RG, Diez-Roux AV, Knirsch CA, Pablos-Méndez A. Neighborhood poverty and the resurgence of tuberculosis in New York City, 1984-1992. *Am J Public Health*. 2001;91(9):1487-1493.
35. Schulz A, Williams D, Israel B, et al. Unfair treatment, neighborhood effects, and mental health in the Detroit metropolitan area. *J Health Soc Behav*. 2000;41(3):314-332.
36. Cubbin C, LeClere FB, Smith GS. Socioeconomic status and injury mortality: individual and neighbourhood determinants. *J Epidemiol Community Health*. 2000;54(7):517-524.
37. Sampson RJ, Raudenbush SW, Earls F. Neighborhoods and violent crime: a multilevel study of collective efficacy. *Science*. 1997;277(5328):918-924.
38. Centers for Disease Control and Prevention (CDC). Neighborhood safety and the prevalence of physical inactivity—selected states, 1996. *MMWR Morb Mortal Wkly Rep*. 1999;48(7):143-146.
39. Catlin TK, Simoes EJ, Brownson RC. Environmental and policy factors associated with overweight among adults in Missouri. *Am J Health Promot*. 2003;17(4):249-258.
40. Fullilove MT, Héon V, Jimenez W, Parsons C, Green LL, Fullilove RE. Injury and anomie: effects of violence on an inner-city community. *Am J Public Health*. 1998;88(6):924-927.
41. Haan M, Kaplan GA, Camacho T. Poverty and health. Prospective evidence from the Alameda County Study. *Am J Epidemiol*. 1987;125(6):989-998.
42. Bosma H, van de Mheen HD, Borsboom GJ, Mackenbach JP. Neighborhood socioeconomic status and all-cause mortality. *Am J Epidemiol*. 2001;153(4):363-371.
43. Yen IH, Kaplan GA. Neighborhood social environment and risk of death: multilevel evidence from the Alameda County Study. *Am J Epidemiol*. 1999;149(10):898-907.
44. Latour J, López V, Rodriguez M, Nolasco A, Alvarez-Dardet C. Inequalities in health in intensive care patients. *J Clin Epidemiol*. 1991;44(9):889-894.
45. Findlay JY, Plenderleith JL, Schroeder DR. Influence of social deprivation on intensive care outcome. *Intensive Care Med*. 2000;26(7):929-933.
46. Ho KM, Dobb GJ, Knuiman M, Finn J, Webb SA. The effect of socioeconomic status on outcomes for seriously ill patients: a linked data cohort study. *Med J Aust*. 2008;189(1):26-30.
47. US Census Bureau. Poverty. Definitions. US Census Bureau Web site. http://www.census.gov/hhes/www/poverty/methods/definitions.html. Accessed August 19, 2010.
48. US Census Bureau. American FactFinder. US Census Bureau Web site. http://factfinder.census.gov. Accessed September 2, 2010.
49. Krieger N, Waterman PD, Chen JT, Soobader MJ, Subramanian SV. Monitoring socioeconomic inequalities in sexually transmitted infections, tuberculosis, and violence: geocoding and choice of area-based socioeconomic measures—the public health disparities geocoding project (US). *Public Health Rep*. 2003;118(3):240-260.
50. Subramanian SV, Chen JT, Rehkopf DH, Waterman PD, Krieger N. Racial disparities in context: a multilevel analysis of neighborhood variations in poverty and excess mortality among black populations in Massachusetts. *Am J Public Health*. 2005;95(2):260-265.
51. Krieger N, Chen JT, Waterman PD, Soobader MJ, Subramanian SV, Carson R. Choosing area based socioeconomic measures to monitor social inequalities in low birth weight and childhood lead poisoning: The Public Health Disparities Geocoding Project (US). *J Epidemiol Community Health*. 2003;57(3):186-199.
52. Krieger N, Zierler S, Hogan J, et al. Geocoding and measurement of neighborhood socioeconomic position: a US perspective. In: Kawachi I, Berkman L, eds. *Neighborhoods and Health*. New York, NY: Oxford University Press; 2003:147-178.
53. Wilson W. *The Truly Disadvantaged*. Chicago, IL: University of Chicago Press; 1987.
54. Saunders MR, Cagney KA, Ross LF, Alexander GC. Neighborhood poverty, racial composition and renal transplant waitlist. *Am J Transplant*. 2010;10(8):1912-1917.
55. Massey D, Denton N. *American Apartheid: Segregation and Making of the Underclass*. Cambridge, MA: Harvard University Press; 1993.
56. GeoLytics, Inc. Geocoding, zip4, site reports. Geolytics Web site. http://www.geolytics.com/USCensus,Geocode,Products.asp. Accessed September 4, 2010.
57. Bureau of the Census. *Census Summary Tape, File 3A (STF 3A)*. Washington, DC: US Department of Commerce; 1990.
58. The Public Health Disparities Geocoding Project Monograph. Harvard School of Public Health, Department of Society, Human Development, and Health Web site. http://www.hsph.harvard.edu/thegeocodingproject/webpage/monograph/povdata.htm. Accessed September 1, 2010.
59. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis*. 1987;40(5):373-383.
60. Quan H, Sundararajan V, Halfon P, et al. Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. *Med Care*. 2005;43(11):1130-1139.
61. Moreno RP, Metnitz PG, Almeida E, et al; SAPS 3 Investigators. SAPS 3—From evaluation of the patient to evaluation of the intensive care unit. Part 2: Development of a prognostic model for hospital mortality at ICU admission. *Intensive Care Med*. 2005;31(10):1345-1355.

62. Sibbald W. Evaluating critical care-using health services research to improve quality. In: Vincent J-L, ed. *Update in Intensive Care Medicine*. Heidelberg, Germany: Springer-Verlag; 2001.
63. Martin GS, Mannino DM, Eaton S, Moss M. The epidemiology of sepsis in the United States from 1979 through 2000. *N Engl J Med*. 2003;348(16):1546-1554.
64. Trespalacios FC, Taylor AJ, Agodoa LY, Abbott KC. Incident acute coronary syndromes in chronic dialysis patients in the United States. *Kidney Int*. 2002;62(5):1799-1805.
65. Lee JE, Sung JH, Ward WB, Fos PJ, Lee WJ, Kim JC. Utilization of the emergency room: impact of geographic distance. *Geospat Health*. 2007;1(2):243-253.
66. Latitude, longitude, and great circles. Pearson Software Consulting Web site. www.cpearson.com/excel/latlong.aspx. Accessed June 1, 2010.
67. Rapoport J, Gehlbach S, Lemeshow S, Teres D. Resource utilization among intensive care patients. Managed care vs traditional insurance. *Arch Intern Med*. 1992;152(11): 2207-2212.
68. Cowper DC, Kubal JD, Maynard C, Hynes DM. A primer and comparative review of major US mortality databases. *Ann Epidemiol*. 2002;12(7):462-468.
69. Sohn MW, Arnold N, Maynard C, Hynes DM. Accuracy and completeness of mortality data in the Department of Veterans Affairs. *Popul Health Metr*. 2006;4:2.
70. Schisterman EF, Whitcomb BW. Use of the Social Security Administration Death Master File for ascertainment of mortality status. *Popul Health Metr*. 2004;2(1):2.
71. Newman TB, Brown AN. Use of commercial record linkage software and vital statistics to identify patient deaths. *J Am Med Inform Assoc*. 1997;4(3):233-237.
72. US Department of Commerce. Social Security Administration's death master file. National technical information service. US Department of Commerce Web site. http://www.ntis.gov/products/ssa-dmf.aspx. Accessed July 10, 2010.
73. Krieger N, Waterman P, Lemieux K, Zierler S, Hogan JW. On the wrong side of the tracts? Evaluating the accuracy of geocoding in public health research. *Am J Public Health*. 2001;91(7):1114-1116.
74. School of Computer Science and Statistics at Trinity College Dublin. Random Integer Generator. Random.org Web site. http://www.random.org/integers/. Accessed November 20, 2010.
75. US Bureau of the Census. American FactFinder Reference Maps. US Bureau of the Census Web site. http://www.factfinder.census.gov/jsp/saff/SAFFInfo.jsp?_pageId=referencemaps&_submeduID=maps_2. Accessed November 20, 2010.
76. Massachusetts Budget and Policy Center. MassBudget. Massachusetts Budget and Policy Center Web site. http://www.massbudget.org. Accessed November 1, 2010.
77. US Census Bureau. United States Census 2000. United States Census Bureau Web site. http://www.census.gov/main/www/cen2000.html. Accessed November 12, 2010.
78. FedStats. Masachusetts MapStats. FedStats Web site. http://www.fedstats.gov/qf/states/25000.html. Accessed November 12, 2010.
79. Krieger N, Chen JT, Waterman PD, Rehkopf DH, Subramanian SV. Race/ethnicity, gender, and monitoring socioeconomic gradients in health: a comparison of area-based socioeconomic measures—the public health disparities geocoding project. *Am J Public Health*. 2003;93(10): 1655-1671.
80. Kawachi I, Berkman L, eds. *Neighborhoods and Health*. New York, NY: Oxford University Press; 2003.
81. Hill ME, Rosenwaike I. The Social Security Administration's Death Master File: the completeness of death reporting at older ages. *Soc Secur Bull*. 2001-2002;64(1):45-51.
82. Social Security Administration. How social security can help you when a family member dies. SSA publication No. 05-10008. Social Security Administration Web site. http://www.ssa.gov/pubs/10008.html. Accessed August 12, 2010.
83. Curb JD, Ford CE, Pressel S, Palmer M, Babcock C, Hawkins CM. Ascertainment of vital status through the National Death Index and the Social Security Administration. *Am J Epidemiol*. 1985;121(5):754-766.
84. Calle EE, Terrell DD. Utility of the National Death Index for ascertainment of mortality among cancer prevention study II participants. *Am J Epidemiol*. 1993;137(2):235-241.
85. Acquavella JF, Donaleski D, Hanis NM. An analysis of mortality follow-up through the National Death Index for a cohort of refinery and petrochemical workers. *Am J Ind Med*. 1986;9(2):181-187.
86. LaVeist TA, Diala C, Torres M, Jackson JS. Vital status in the National Panel Survey of Black Americans: a test of the National Death Index among African Americans. *J Natl Med Assoc*. 1996;88(8):501-505.
87. Eschbach K, Ostir GV, Patel KV, Markides KS, Goodwin JS. Neighborhood context and mortality among older Mexican Americans: is there a barrio advantage? *Am J Public Health*. 2004;94(10):1807-1812.
88. Knaus WA, Draper EA, Wagner DP, Zimmerman JE. APACHE II: a severity of disease classification system. *Crit Care Med*. 1985;13(10):818-829.
89. Quach S, Hennessy DA, Faris P, Fong A, Quan H, Doig C. A comparison between the APACHE II and Charlson Index Score for predicting hospital mortality in critically ill patients. *BMC Health Serv Res*. 2009;9:129.
90. Gottlieb SS. Dead is dead—artificial definitions are no substitute. *Lancet*. 1997;349(9053):662-663.
91. Lauer MS, Blackstone EH, Young JB, Topol EJ. Cause of death in clinical research: time for a reassessment? *J Am Coll Cardiol*. 1999;34(3):618-620.
92. Preen DB, Holman CD, Spilsbury K, Semmens JB, Brameld KJ. Length of comorbidity lookback period affected regression model performance of administrative health data. *J Clin Epidemiol*. 2006;59(9):940-946.
93. Lee DS, Donovan L, Austin PC, et al. Comparison of coding of heart failure and comorbidities in administrative and clinical data for use in outcomes research. *Med Care*. 2005;43(2):182-188.
94. Pappas G, Queen S, Hadden W, Fisher G. The increasing disparity in mortality between socioeconomic groups in the United States, 1960 and 1986. *N Engl J Med*. 1993;329(2): 103-109.
95. Wilkinson RG. Income distribution and life expectancy. *BMJ*. 1992;304(6820):165-168.
96. Harris MI. Noninsulin-dependent diabetes mellitus in black and white Americans. *Diabetes Metab Rev*. 1990;6(2):71-90.
97. Fang J, Madhavan S, Alderman MH. The association between birthplace and mortality from cardiovascular causes among black and white residents of New York City. *N Engl J Med*. 1996;335(21):1545-1551.
98. Pickle LW, Mungiole M, Gillum RF. Geographic variation in stroke mortality in blacks and whites in the United States. *Stroke*. 1997;28(8):1639-1647.
99. Committee on Understanding and Eliminating Racial and Ethnic Disparities in Health Care, Institute of Medicine. *Unequal Treatment: What Healthcare Providers Need to Know about Racial and Ethnic Disparities in Health Care*. Washington, DC. National Academy Press; 2002.