



System Failure: The Geographic Distribution of Sepsis-Associated Death in the USA and Factors Contributing to the Mortality Burden of Black Communities

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Abstract

Sepsis is deadly and costly to health care systems, but these costs are disproportionately born by Black patients. Little empirical work has established the geographic patterning of sepsis or its area-level correlates. This study illustrates the geography of sepsis-associated death and racial composition of US counties with area socioeconomic indicators, health care access, and population health. Cartographic and spatially explicit analyses utilize mortality data from the National Cancer Institute and county data from the American Community Survey, Area Health Resource File, and County Health Rankings. Death rates are highest in the South, Southeast, and Appalachia. Counties disproportionately populated by Black people have higher death rates and associated risk indicators including poor air quality and vaccination coverage, socioeconomic distress, and impaired access to high-quality health care. Spatial Durbin error models suggest that conditions in nearby counties may also influence death rates within focal counties. Racial disparities in sepsis-associated death can be narrowed with improved health care equity—including immunization coverage—and by reducing socioeconomic distress in Black communities. Policy options for achieving these ends are discussed.

Background

Sepsis is a potentially life-threatening syndrome of organ dysfunction caused by the body's response to an infection. Underlying causes of sepsis include bacterial respiratory infections like pneumonia; viral and fungal infections; and non-infectious insults such as trauma, burns, and pancreatitis [1]. Recently, an elevated risk for sepsis-associated death has been linked to novel coronavirus SARS-CoV-2 [2, 3]. Clinical records indicate that approximately two million adults are hospitalized annually for sepsis in the USA and the system-wide inflammation associated with severe cases is linked to over 250,000 deaths per year [4]. Indeed, some estimates suggest that sepsis is implicated in one-third to one-half of hospital deaths despite being the cause of a minority of hospitalizations [5]. Sepsis is also financially burdensome, costing the health care system over \$38 billion annually—the costliest condition associated with hospitalization in the USA [6].

Concerningly, the septic mortality rate has recently doubled in the USA, from 21.9 per 100,000 in 1979 to 43.9 in 2000 [7]. Incidence has increased further since 2003, though this resulted in part from changes to diagnostic criteria that made sepsis diagnoses more inclusive of milder cases [8]. Irrespective of the criteria used, the risk for sepsis-associated death varies by race and ethnicity, with Black persons far more likely to die of sepsis than their non-Hispanic White counterparts. It is the tenth leading cause of death for Black Americans who die from sepsis at twice the rate of Whites [9, 10], making it a highly disparate cause of death in the USA.

Despite its prevalence, financial costs, and the racial asymmetries that characterize its incidence, little is known about the geographic distribution of sepsis-associated death across the USA nor its area-level correlates. Learning more about the spatial structure of sepsis-associated death and the community features associated with it can inform population health initiatives and hospital system reform to lower the incidence of septic mortality for Black and White populations. Accordingly, this study (1) illustrates the spatial distribution of sepsis-associated death across US counties, (2) empirically estimates clustering of counties on the basis of shared “high” and “low” death rates, and (3) applies both a novel spatially explicit correlational method and spatial

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Durbin regression modeling to identify correlates of sepsis death rates. Findings from prior mortality research—including investigations of sepsis—guide the identification of relevant community features.

Racial disparities in sepsis outcomes are caused by three likely sources: differential treatment of patients in the same hospital, differential quality of care for patients in different hospitals, and factors attributed to community or personal risks. Evidence, while equivocal, suggests that all three are relevant. Racial differences in sepsis outcomes are smallest in studies focused on Black and White patients treated in the same hospital, and in some cases these differences are to the advantage of Black patients [11–13]. By contrast, inter-hospital differences suggest larger disparities between patients in Black- versus White-serving hospitals. For instance, a study in New York state found that hospitals serving disproportionately Black populations were less likely to adhere to evidence-based guidelines for sepsis management [14]. Net of illness severity, Black patients are generally less likely to have common sepsis management measures implemented including timely administration of antibiotics [15]. Such differences appear to be driven by inter-hospital differences in health care quality and training of medical professionals [15, 16], findings that speak to the importance of the profound racial segregation of patient populations [17, 18].

The segregation of health care systems exacerbates racial disparities in health and survival. All-cause mortality rates vary across the USA according to area-level racial composition [19, 20] and Black-serving hospitals routinely score poorly on nearly all patient outcome metrics [21, 22]. In the case of severe sepsis, even health care services outside of one's own health service area influence local inequities. Black patients on mechanical ventilation are less likely than Whites to be transferred to larger acute-care hospitals better equipped to treat severe cases [23], hinting at the possibility of regional disparities in treatment and access to care outside of one's immediate community.

Given that most sepsis cases present symptoms at the time of hospital admission [8, 24], community factors are likely to also differentiate sepsis risks between Black and White people. Racial segregation of patient populations indexes other resource disparities including poverty and low rates of health insurance coverage [25, 26], adverse environmental conditions [27], service deficits including food deserts and low vaccination rates [28–30], and high prevalence of comorbidities caused by upstream social inequities and systemic racism [31, 32].

To date, there are no studies applying spatially explicit methods to document the geographic distribution of septic mortality in the USA and its community correlates including health care, socio-environmental, and demographic factors. A spatial approach to identifying areas heavily impacted by sepsis-associated death could optimize resource allocation

to health care systems unable to cope with this population health challenge. The current study addresses this gap via cartographic methods identifying the geographic distribution of septic mortality across US counties. After establishing the geography of sepsis-associated death, spatially explicit bivariate and multivariable spatial autoregressive models are used to assess whether associations between county-level racial composition and septic mortality rates are robust to adjustment for area health care access, sociodemographic characteristics, and community health risks. These aims are achieved with mortality data from the National Cancer Institute (NCI) alongside data from the American Community Survey (ACS), Area Health Resource File (AHRF), and the County Health Rankings (CHR) project.

Methods

Dependent Variables

Data on the outcome—county-level sepsis-associated death rates—were obtained using the Surveillance, Epidemiology, and End Results (SEER)*Stat tool maintained by the NCI. For the purposes of mapping and exploratory spatial data analysis, age-adjusted death rates per 100,000 in the population were used. Following common practice in mortality research [33], spatial autoregressive models used unadjusted death rates while controlling for county age composition. Estimates combine mortality events between 2015 and 2019 and omit counties and equivalents outside of the continental US or with fewer than 10 deaths in the study period ($n=933$), yielding an analytic sample of 2210 counties.¹

Correlates

Five-year files from the 2015–2019 ACS were used to operationalize the following: racial composition (percent non-Hispanic Black), age composition, percent foreign-born population, county income inequality (Gini coefficient), percent age 25+ without a high school diploma/equivalent, and a binary indicator for rural location based on Beale Rural–Urban Continuum Codes.

Data on county-level health care access and quality were drawn from the AHRF, a database that has been maintained by the Health Resources and Services Administration (HRSA) since the 1970s. The AHRF collects data from over 50 sources such as the American Hospital Organization, the American Medical Association, and the US Census Bureau for over 6000 points of interest across all 50 states. Measures

¹ Omitted counties in the continental US were largely rural places with very small populations averaging fewer than 9000 inhabitants.

from the AHRF used here include the following: a binary variable indicating that there is no hospital within a county (= 1 if so; 14.3% of all counties), admissions per capita, MDs per capita, environmental pollution operationalized as the average daily recorded particulate matter (for 2016 only), and the rate of preventable hospital stays (i.e., treatments that could have been provided by an ambulatory health care provider) as well as the Medicare readmission rate—two widely-assessed measures of area health care quality that vary by patient race and community racial composition [34–37].

Population health data were drawn from the CHR, a collaborative program of the Robert Wood Johnson Foundation and the University of Wisconsin that evaluates and compares the health and demographics of nearly every county in all 50 US states. The project collects data on programs, policies, and health factors related to county-level physical environment, social and economic characteristics, clinical care, and health behaviors. The following measures from the CHR are used here: percent of those under age 65 without health insurance and influenza vaccination rates, included because prior research identifies respiratory illnesses like influenza and other ambient threats including poor air quality as risk factors for sepsis [38, 39]. Sensitivity analyses incorporate crude deaths from diseases of the heart and influenza or pneumonia (also derived from the SEER*Stat database) and rates of unintentional drug overdose deaths from the CDC Wonder database. All variables are measured within a focal county and among all counties within a focal county's neighborhood matrix, which is defined in the forthcoming sections.

Analysis

Choropleth mapping is used to illustrate geographic variation of septic mortality rates across counties in the continental US. Spatial autocorrelation for the nation was assessed with the Moran's I statistic based on a 3-nearest neighbors contiguity matrix. Following Chi and Zhu [40], the 3-nearest neighbors matrix was chosen as it yielded the highest Moran's I value across adjacency-based (e.g., Queen's and Rook's 1st–4th order matrices) and distance-based (e.g., k -nearest neighbors, inverse-distance matrices) alternatives.

A complementary map of clustering utilizes the local Moran's I statistic to show county clusters sharing "high" and "low" sepsis death rates. Local Moran's I , a local spatial autocorrelation statistic, is widely used to assess whether the spatial distribution of data is random or alternatively characterized by statistically significant (i.e., $p < 0.05$) clustering of similar values beyond what random chance would predict. It is complementary to the global Moran's I in that it is a decomposition of the global measure, providing an

empirical estimate of the extent of spatial clustering at local levels like counties.

Associations among hypothesized correlates and (a) septic mortality rates as well as (b) county percent Black population were estimated using Lee's L , a spatially explicit bivariate measure of association that simultaneously accounts for the spatial autocorrelation of an outcome and its aspatial correlation with a second variable [41]. Lee's L is given by the following:

$$L_{X,Y} = \frac{\sum_i [(\sum_j w_{ij}(x_j - \bar{x})) \cdot (\sum_j w_{ij}(y_j - \bar{y}))]}{\sqrt{\sum_i (x_i - \bar{x})^2} \sqrt{\sum_i (y_i - \bar{y})^2}} \quad (1)$$

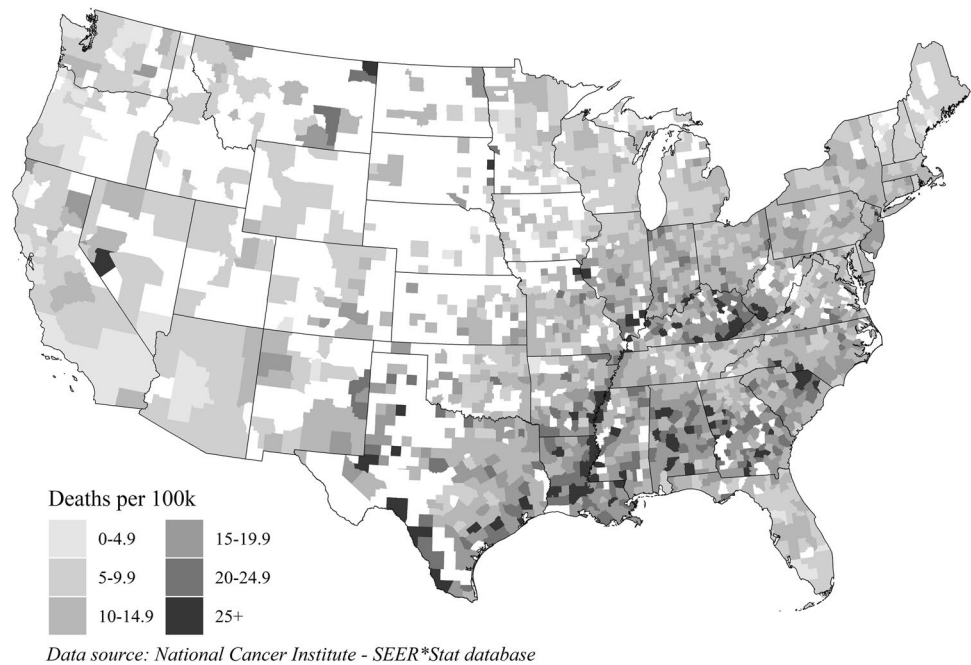
...where w_{ij} is a row-standardized spatial weight for every i^{th} county in each j^{th} neighborhood. Readers will identify in this equation the amalgam of Pearson's r and Moran's I statistics to produce $L_{X,Y}$ —a measure of both bivariate correlation and spatial autocorrelation ranging from -1 (indicating an inverse relationship between two variables) to +1 (indicating a positive relationship). For geographically structured outcomes, neglecting to account for spatial autocorrelation may yield biased correlation coefficients—a problem the Lee's L statistic solves.

Finally, spatial autoregressive models were estimated to assess multivariable associations among study variables. In selecting the appropriate model for this task consideration must be paid to the hypothetical spatial properties of the associations under investigation. Given that individuals in need of medical care often cross county boundaries to receive it, the mortality rates prevailing in one county are quite likely to affect those in nearby counties. Spatial lag models are frequently used to evaluate such a scenario, but these models are limited to exploring the autoregressive traits of outcomes and not model covariates [42], a challenge shared by the equally common spatial error model. The spatial Durbin error model meets this challenge by incorporating effects for both a spatially lagged dependent variable and sets of explanatory variables calculated for focal and nearby units (i.e., spatially lagged independent variables). The three central components of the spatial Durbin model are given below in Eq. 2:

$$y = \rho Wy + al_n + X\beta + WX\theta + \varepsilon \\ \varepsilon \sim N(0, \sigma^2 I_n), \quad (2)$$

where y represents an $n \times 1$ vector of county septic mortality rates, W represents the spatial weights matrix, Wy represents the spatially lagged mortality rates from nearby counties, and ρ represents the effect of Wy —the spatial autoregressive coefficient. Additional terms denote an intercept (al_n), X represents an $n \times k$ matrix of k -independent variables whose relationship with the dependent variable are described by β , and WX representing the spatially lagged

Fig. 1 County sepsis-associated death rates, 2015–2019



independent variables with θ describing their association with the outcome. Finally, an error term (ε) follows a normal distribution with mean of 0 and variance of $\sigma^2 I_n$, with I_n representing an $n \times n$ identity matrix. Combined, the features of the spatial Durbin model allow for simultaneous estimation of the association between county-level sepsis-associated death rates, within-county covariates, and lagged effects of covariates and the outcome itself from counties sharing a spatial neighborhood. All analytic and cartographic work was performed in RStudio v1.3.1073 [43].

Results

Figure 1 provides a snapshot of the geographic distribution of sepsis-associated death rates, binned into equal intervals that approximate nationwide sextiles in mortality rates. Among counties with valid mortality data, the average sepsis death rate was 13.5 (SD=6.2) with skew of 1.1 indicating modest right skew. A visual inspection of the geography of sepsis death rates hints at the spatial structure of septic mortality. With few exceptions, the highest rates of sepsis-associated death are found in the South, South Atlantic, and Appalachian regions. Rates in these regions—the highest in the country—reach a maximum of 52.9 deaths per 100,000 in Kentucky's Perry County, and 100 counties in these three regions had rates surpassing 25 per unit of population (out of 112 total counties with death rates surpassing this figure).

Geographic clustering of sepsis death rates is empirically demonstrated by the Moran's I statistic, equal to

0.60 for the nation. This estimate is based on the 3-nearest neighbors contiguity matrix with Monte Carlo simulated p value < 0.001 at 1000 iterations. Figure 2 provides an empirical assessment of the geographic concentration of sepsis death rates with local Moran's I values capturing the extent to which counties with high and low death rates cluster together in space. County clusters of high death rates are evident in Texas, Louisiana, Arkansas, Mississippi, Alabama, Georgia, South Carolina (in the northeastern Pee Dee region), and in the Appalachian region within Kentucky and southwestern West Virginia. Clusters of counties with low death rates are concentrated in states along the west coast, Minnesota, Wisconsin, and Florida, and in New Hampshire and Vermont. Clustering was either not statistically significant in the remaining regions or impossible to estimate given sparse population counts and suppressed mortality data.

Figure 3 provides a descriptive portrait of the area-level correlates of sepsis death rates. Bivariate associations described in Fig. 3 are derived from Lee's spatial correlation method described earlier and display relationships between (1) sepsis death rates and (2) racial composition (i.e., percent Black) with study covariates. Beginning with demographic measures, Fig. 3 reveals higher septic mortality rates in counties with larger Black populations, higher shares of adults without high school diplomas, greater income inequality, and in rural counties. Septic mortality rates are lower in counties with more foreign-born persons. A similar pattern is shown with respect to racial composition: counties with greater shares of Black persons have fewer foreign-born persons, lower aggregate educational attainment, greater income inequality, and are more likely to be rural.

Fig. 2 County sepsis death rate clusters, 2015–2019

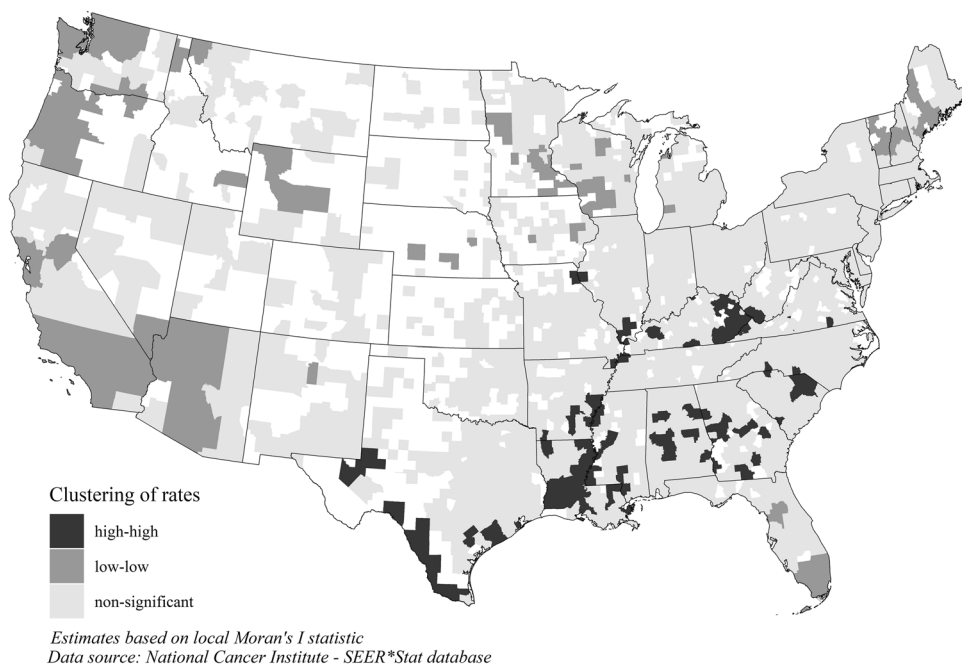
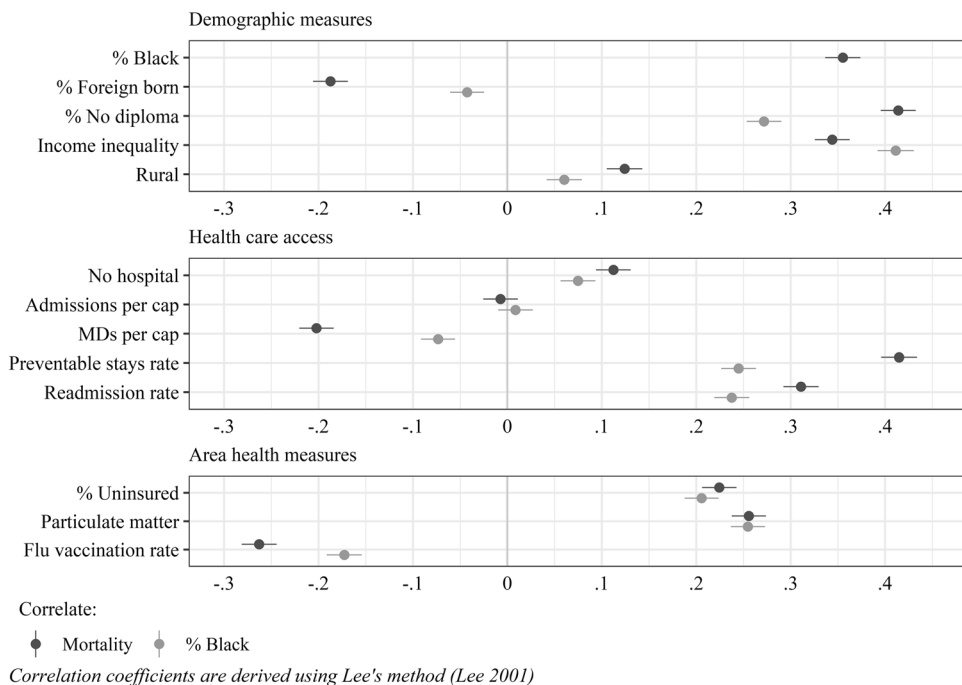


Fig. 3 Correlates of septic mortality rates and county racial composition

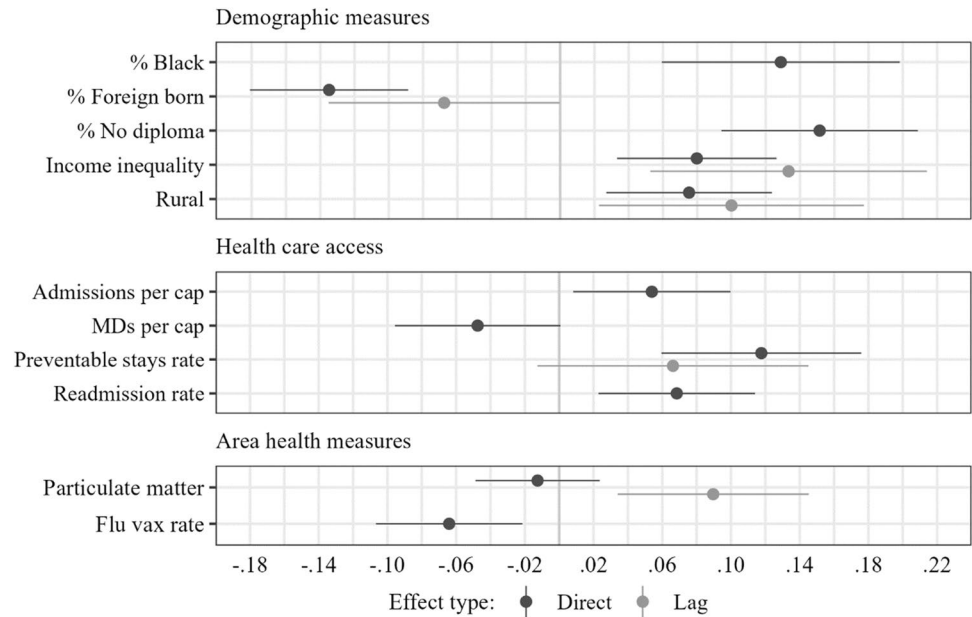


The second panel of Fig. 3 focuses on covariates related to health care access. As with the demographic measures in the first panel, relationships between mortality rates and racial composition with health care measures are largely concordant. Mortality rates are higher in counties with no hospital and with higher rates of preventable hospital stays and readmission rates—all of which are positively related to the proportion of the county population comprised by Black people. A protective factor—MDS per capita—is inversely

related to both mortality rates and the proportion of Black people in the population.

The third panel concerns area health measures, showing positive associations between uninsurance rates and average daily particulate matter (i.e., air pollution) with both mortality rates and percent Black. Conversely, flu vaccination rates are inversely associated with mortality rates as well as the share of the Black population. All associations have been tested on a subsample of counties with at least

Fig. 4 Spatial Durbin error model of sepsis death rates and county characteristics. Notes: Model parameters are standardized and adjusted for county age composition, autocorrelated error term, and all other measures shown in Fig. 3. Error bars correspond to 95% confidence intervals, which indicate a p -value $> .05$ when overlapping with the vertical line at zero on the x-axis



one hospital, bearing results that are statistically and substantively similar to those presented here.

Bivariate associations are instructive, but leave unanswered questions regarding the robustness of specific associations between area-level measures and sepsis. Figure 4 summarizes results from a spatial Durbin model that allows for simultaneous adjustments for spatial autocorrelation of the outcome and all study covariates measured within focal counties and neighboring communities. These estimates are presented as standardized coefficients, corrected for heteroskedasticity via Huber-White sandwich estimators following a Breusch-Pagan test that indicated a need for such adjustment. For parsimony, Fig. 4 is limited to variables with either significant ($p < 0.10$) direct or lagged associations with the outcome; all other coefficients are not shown but are included in the underlying model.

Results in the first panel show a positive and significant relationship between the percent of a county comprised of Black residents and its sepsis death rate ($b = 0.13$, $SE = 0.04$, $p < 0.001$), net of all other covariates in the model. Conversely, sepsis death rates are lower in counties with larger shares of the foreign-born population ($b = -0.13$, $SE = 0.02$, $p < 0.001$) and those near counties with similarly dense immigrant populations ($b_{lag} = -0.07$, $SE = 0.03$, $p < 0.05$). The fraction of those without a high school diplomas is linked to high death rates ($b = 0.15$, $SE = 0.03$, $p < 0.001$), as is income inequality in the focal county ($b = 0.08$, $SE = 0.02$, $p < 0.001$) and income inequality in nearby counties ($b = 0.13$, $SE = 0.04$, $p < 0.01$). Rural counties also have higher death rates than non-rural places ($b = 0.07$, $SE = 0.02$, $p < 0.01$), as do counties flanked by rural places ($b = 0.10$, $SE = 0.04$, $p < 0.01$).

Associations of sepsis death rates with measures of health care quality and access are shown in the second panel. Counties with higher hospital admissions per capita also have higher sepsis death rates, but this association is only marginally significant ($b = 0.05$, $SE = 0.02$, $p = 0.067$). The number of MDs per capita is inversely associated with death rates, though this too is a marginally significant association ($b = -0.05$, $SE = 0.03$, $p = 0.074$). In terms of health care quality indicators, both the preventable hospital stays rate ($b = 0.11$, $SE = 0.03$, $p < 0.001$) and the hospital readmission rate among Medicare beneficiaries ($b = 0.07$, $SE = 0.02$, $p < 0.01$) are associated with higher sepsis death rates. Lagged preventable hospital stays rates are also positively associated with the sepsis death rates of focal counties, but only marginally so ($b = 0.07$, $SE = 0.04$, $p = 0.07$).

The final panel of Fig. 4 depicts associations between sepsis death rates and county-level pollution and influenza vaccination coverage. Results reveal a significant and inverse association between the influenza vaccination rate and death rates ($b = -0.06$, $SE = 0.02$, $p < 0.01$), and a positive association between lagged daily fine particulate matter levels and death rates in a focal county ($b_{lag} = 0.09$, $SE = 0.03$, $p < 0.01$). To reiterate, the estimates in Fig. 4 are adjusted for the age-composition of counties and all covariates—direct and lagged—shown in Fig. 3.

Importantly, adding covariates to the Durbin model attenuates the coefficient for the percent Black in a county. In a minimally adjusted model controlling only for age composition, the standardized coefficient for percent Black is equal to 0.297 ($SE = 0.03$, $p < 0.001$). Following adjustments for other demographic variables this is further reduced by 41% ($b = 0.176$, $SE = 0.03$, $p < 0.000$), and another 18%

once measures of health care access are added ($b = 0.145$, $SE = 0.03$, $p < 0.000$). Finally, adding measures of the uninsurance rate, air pollution, and influenza vaccination reduces the coefficient for percent Black by 11% ($b = 0.129$, $SE = 0.02$, $p < 0.000$)—for a total 57% reduction in the magnitude of the coefficient for racial composition.

Sensitivity Analyses

Sensitivity tests were conducted to determine if the results in Fig. 4 are robust to adjustment for conditions that commonly cause sepsis including heart disease, pneumonia and influenza, and intravenous drug use (IVD). Supplemental models were estimated separately, rotating crude mortality rates for each cause of death iteratively, with parameters reported as standardized coefficients. Results show that cardiac mortality rates were positively and significantly associated with sepsis death rates ($b = 0.25$, $p < 0.000$), though adding this variable did not change model parameters statistically nor substantively. This includes the standardized coefficient for percent of the county population comprised of Black people ($b = 0.13$ in Fig. 4 as well as the supplemental model).

Adding the measure of IVD-related mortality ($b = 0.14$, $p < 0.000$) reduced one variable—the Medicare beneficiary readmission rate—to a non-significant level, but led to an increase in the magnitude of the racial composition measure ($b = 0.21$, $p < 0.000$), evidence of effect suppression. This result must be interpreted cautiously though, as the size of the sample used to estimate this supplemental model ($N = 858$) is considerably smaller than the main analytic sample ($N = 2,210$) due to data suppression across many counties with few or no deaths from unintentional overdose. Finally, adding mortality rates from pneumonia or influenza yields a significant standardized coefficient ($b = 0.25$, $p < 0.000$) while leaving all other model parameters effectively unchanged—including the coefficient for the influenza vaccination rate ($b = -0.05$ in the supplemental model versus -0.06 in the main model).

Discussion

Sepsis is a challenge to the US health care system, patient survival, and population health equity. Black people face nearly double the risk of dying from sepsis as non-Hispanic Whites. Prior work suggests intra-hospital variation in the implementation of sepsis protocols according to patient race contributes to this disparity [14], but the well-documented and considerable racial segregation of patient populations [17] hints at inter-hospital explanations as well. This study documents the geographic distribution of septic mortality rates across counties in the continental US and identifies correlates associated with county-level death rates and racial

composition using a spatially explicit bivariate method not widely applied in prior work on mortality.

The results indicate geographic clustering of high septic mortality rates in certain US regions—particularly the South, Southeast, and Appalachia. Counties with the highest rates tend to be disproportionately populated by Black people and lack access to high-quality health care as evidenced by the significant association between higher septic mortality rates and preventable hospital stays, hospital readmissions, fewer MDs per capita, and the lack of any hospital at all. On average, these same counties also present higher income inequality, lower educational attainment, and area-health disadvantages including low insurance coverage, worse air quality, and low vaccination coverage. Each indicator associated with the septic mortality rate is also significantly associated with the proportion of the Black population and in the same direction.

Descriptive results are largely consistent with multivariable patterns revealed by the spatial Durbin models. Net of all other controls and effects from nearby counties, counties with higher preventable stays and readmission rates have higher sepsis death rates. When controlling for these two variables, the effect of county racial composition is also attenuated, suggesting that Black communities are deprived of high-quality care and are more vulnerable to septic mortality as a result. Some factors demonstrate a protective effect, but those too are lacking in Black communities. Durbin regression results show that sepsis death rates are lower in counties with higher vaccine coverage, but correlational evidence indicates that vaccine coverage is lower in counties with larger Black populations.

These findings must be qualified alongside several limitations. First, the outcome was measured with administrative data on cause of death and cannot distinguish between community- versus hospital-acquired cases of sepsis. Prior work suggests that administrative reports may overstate the prevalence of fatal sepsis versus clinical data [8, 44], and it is well-documented that hospital-acquired sepsis is far more fatal than community-acquired cases [24]. It is unclear whether the disagreement between administrative and clinical data is geographically structured, or if the patterns shown here would vary by the context of infection. Second, the common practice of suppressing counties with insufficient death counts could bias the sample toward larger counties, though evidence is equivocal. The counties omitted from this analysis represent less than two percent of the continental US population and our analytic sample includes 157 rural counties, roughly seven percent of the sample. Even so, the unique health challenges faced by rural communities including accelerating hospital closures warrants focused attention. Third, some measures approximating local health care quality are imperfect. Medicare readmission rates, for example, may be more reflective of the reluctance of

health care administrators to treat minority patients for fear of compromising hospital performance metrics [34]. Using the number of medical doctors per capita as a proxy for the availability of local health care professionals may also be limited as it omits other practitioners—nurses, physician assistants, doctors of osteopathy—who contribute to sepsis care. Fourth, annual fluctuations could influence the study results, especially in the case of shocks related to sepsis etiology (e.g., an unusually severe flu and pneumonia season). Finally, causation is impossible to establish with the data used here.

With these limitations in mind, one tentative conclusion from the current study is that impediments to preventative care and medical treatment, socioeconomic inequalities, and environmental insults distinguish the risk for sepsis-associated death between Black and White communities. This grim finding reveals several opportunities for immediate action. The COVID pandemic exposed longstanding inequities built into the US immunization infrastructure [45] and administrative burdens that penalize communities of color [46]. Improving equity in the immunization infrastructure would potentially reduce racial disparities in sepsis-associated death. Compared to non-Hispanic Whites, rates of vaccination against respiratory illnesses are lower in Black communities [47], especially among those most vulnerable to septicemia [30]. Results from the current study suggest that improved efforts to narrow racial inequities of influenza and pneumoniae (PCV-13 and PPSV-23) vaccination would reduce the racial gap in sepsis-associated death [48]. Because bacterial infections are more common causes of sepsis than viral infections [49], improving pneumococcal vaccination in minoritized communities with unmet vaccine needs may prove especially beneficial.

These findings also point to long-range goals of ameliorating socioeconomic inequities between Black and White communities. Across all manner of morbidities and causes of death, income inequality is consistently associated with population health disparities net of absolute poverty [50]. Results from this study align with prior work on the racial wealth gap and extend previous findings on income inequality to the case of sepsis-associated death. Addressing socioeconomic disparities between Blacks and Whites is critical to population health equity. Residential location, and the amenities and risks that come with it, is a fundamental contributor to health [31], and like prior work has shown [27], counties with greater shares of Black residents are beset by both poorer health and worse environmental conditions than communities with fewer Black people. Yet structural racism, evidenced by discriminatory practices among housing professionals [51] and employers [52], deprives Black people of access to housing in communities rich with health resources and free of environmental risks like pollution [53]. Even so, fair housing complaints filed

by Black complainants are less likely to receive favorable outcomes than those filed by members of other groups [54] despite their disproportionate vulnerability to housing discrimination [55]. Reducing variability in the socialization of and processes used by local and state agencies managing Title VIII complaints may provide relief for victims of prejudicial treatment in housing markets [54].

Relatedly, there must be expanded avenues of redress for those in health care systems that systematically deprive Black people of the same quality of health care available in areas predominated by White patients. Racial residential segregation establishes racially distinct health service areas [17], and equitable access to high-quality health care is further challenged by decisions within health care systems to redirect resources from unprofitable service areas—rural, low-income, minority-serving—to more lucrative areas. Currently, legal options are limited for patients adversely affected by such decisions, but these could be strengthened with greater federal oversight of Title VI compliance [56]. Additionally, programs could be developed through the Center for Medicare and Medicaid Innovation (CMMI) incentivizing Black-serving hospitals to provide sepsis care that is consistent with best practices and state mandates [14]. Given the matrix of correlates associated with septic mortality, a broad approach that improves access to high-quality health care, narrows socioeconomic disparities, and eliminates environmental injustices is needed to reduce Black-White inequities in fatal sepsis outcomes.

Author Contributions The sole author of this study completed all aspects of conceptualization, methodology, analysis, and writing independently.

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Data Availability Data are public-use and available via the following websites:

<https://data.hrsa.gov/topics/health-workforce/ahrf>
<https://www.countyhealthrankings.org/>
<https://seer.cancer.gov/seerstat/>

Code Availability Rstudio program code available upon request.

Declarations

Competing Interests The author declare no competing interests.

Ethics Approval Study was deemed exempt from review by the Colorado Multi-Institutional Review Board (COMIRB) due to the observational nature of the study and use of aggregate data.

Consent to Participate Consent to participate was not obtained as this study is based on aggregate data and aggregated outcome measures of mortality that do not involve living individuals.

Consent to Publish Consent for publication was not obtained as this study is based on aggregate data and aggregated outcome measures of mortality that do not involve living individuals.

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