Mortality and Health Outcomes in North Carolina Communities Located in Close Proximity to Hog Concentrated Animal Feeding Operations

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BACKGROUND Life expectancy in southeastern North Carolina communities located in an area with multiple concentrated animal feeding operations (CAFOs) after adjusting for socioeconomic factors remains low. We hypothesized that poor health outcomes in this region may be due to converging demographic, socioeconomic, behavioral, and access-to-care factors and are influenced by the presence of hog CAFOs.

METHODS We studied mortality, hospital admissions, and emergency department (ED) usage for health conditions potentially associated with hog CAFOs—anemia, kidney disease, infectious diseases, and low birth weight (LBW)—in North Carolina communities located in zip codes with hog CAFOs (Study group 1), in zip codes with > 215 hogs/km² (Study group 2), and without hog CAFOs (Control group). We compared cause-specific age-adjusted rates, the odds ratios (ORs) of events in multivariable analyses (adjusted for 6 co-factors), and the changes of ORs relative to the distance to hog CAFOs.

RESULTS Residents from Study groups 1 and 2 had higher rates of all-cause mortality, infant mortality, mortality of patients with multimorbidity, mortality from anemia, kidney disease, tuberculosis, and septicemia, and higher rates of ED visits and hospital admissions for LBW infants than the residents in the Control group. In zip codes with > 215 hogs/km², mortality ORs were 1.50 for anemia (P < 0.0001), 1.31 for kidney disease (P < 0.0001), 2.30 for septicemia (P < 0.0001), and 2.22 for tuberculosis (P = 0.0061).

LIMITATIONS This study included a lack of individual measurements on environmental contaminants, biomarkers of exposures and co-factors, and differences in residential and occupational locations.

CONCLUSION North Carolina communities located near hog CAFOs had higher all-cause and infant mortality, mortality due to anemia, kidney disease, tuberculosis, and higher hospital admissions/ED visits of LBW infants. Although not establishing causality with exposures from hog CAFOs, our findings support the need for future studies to determine factors that influence these outcomes, as well as the need to improve screening and diagnostic strategies for these diseases in North Carolina communities adjacent to hog CAFOs.
with occupational or residential exposure to CAFOs. These included an increased risk of anemia and kidney disease (which may serve as an indicator of chronic exposure to toxins) [23-26], miscarriage [27], and LBW infants (which may serve as an indicators of maternal and fetal health) [2]. In addition, a higher prevalence and broader spectrum of antibiotic-resistant microorganisms in areas adjacent to hog CAFOs [28-30] has raised concerns about infections in both occupational and residential settings [31]. Therefore, the outcomes of anemia and kidney disease, acute infection (septicemia) and chronic communicable infection (tuberculosis), and LBW infants were analyzed as indicators of health in communities adjacent to hog CAFOs.

We focused our study on assessing the outcomes of these specific disorders in residential communities in southeastern North Carolina. Our objective was to determine whether, or to what extent, poor health outcomes are associated with the additional impact of hog CAFOs beyond disparities associated with demographics, socioeconomic characteristics, behavioral risks factors, or access to medical care. Furthermore, these health conditions served as potential opportunities for interventions if the determined health outcomes were poor.

Materials and Methods

Data. Data on disease-specific mortality were obtained from a publicly available data source at the State Center for Health Statistics for 2007-2013 [32]. Data on emergency department (ED) visits and hospital admissions were obtained from the Healthcare Cost and Utilization Project’s (HCUP) State Emergency Department Database (SEDD) [33] and State Inpatient Database (SID) [34] for 2007-2013. The North Carolina analysis represents part of the larger study on health outcomes in the communities adjacent to hog CAFOs that includes other US states with commercial hog production (e.g., Iowa and Minnesota). Therefore, we used the HCUP’s state-specific database containing the data in a uniform format facilitating multi-state comparisons and analyses of geographic patterns and time trends in health care utilization, access, and outcomes across multiple US states. The SEDD captures discharge information on all ED visits that do not result in an admission and contains more than 100 clinical and non-clinical variables. Information on patients that are initially seen in the ED and then admitted to the hospital is included in SID, which encompasses almost 97% of all US hospital discharges. The SID and SEDD data for North Carolina for the period analyzed in this study had several issues that were addressed in performed analysis. For example, the 2011-2012 North Carolina SEDD included 2 types of erroneous records, such as duplicated records for ED visits that did not result in an admission to the same hospital and records for ED visits that did result in an admission to the same hospital. The SID dataset for North Carolina for 2007-2008 had problems with the coding of discharge disposition. These issues were identified and resolved according to the guidelines provided by the HCUP Data Center.

The list of swine animal operations registered in North Carolina contained information on geographic locations and the number of swine in each CAFO facility. Information was obtained from the North Carolina Division of Water Resources (NC DWR) for the year 2009. The animal operations are defined by General Statute 143-215.10B as feedlots involving 250 or more swine with a liquid waste management system.

Zip-code-level data on median household income (scaled by $10,000) and education level (defined as a percentage of people aged 25+ who attained an educational level higher than a bachelor’s degree) were obtained from the 2010-2014 American Community Survey. County level data on the numbers of primary care providers (per 100,000 residents) and the percent of uninsured individuals was obtained from the Area Health Resources Files (AHRF) for 2008 and 2010-2013. County level data on prevalence of current smokers in age-specific groups were obtained from the Behavioral Risk Factor Surveillance System (BRFSS, CDC) for 2008-2013.

Methods. We studied the health outcomes in two study groups. Study group 1 included the residents of North Carolina communities located in zip codes with hog CAFO(s): 221 zip codes with approximately 2,260,000 residents. Study group 2 represented a subset of Study group 1. This group included North Carolina communities located in zip codes with the highest upper quartile of hog density (with > 215 hogs/km²): 56 zip codes with approximately 400,000 residents. North Carolina communities located in zip codes without hog CAFOs represented the Control group: 601 zip codes with approximately 7,200,000 residents. Geographic locations of zip codes for two Study groups and the Control group are shown in Figure 1.

We compared disease-specific mortality, hospital admissions, and ED visits in these groups for the 2007-2013 period. All-cause, infant mortality, and outcomes of anemia, kidney disease, tuberculosis, septicemia, and LBW infants (see Appendix for respective ICD codes) were studied as the health indicators, with disease-specific mortality as primary outcome. The main predictor was the presence of a hog CAFO in a given zip code. Analyses were performed for underlying cause of death/primary diagnosis and for underlying-plus-secondary causes of death/primary-plus-secondary diagnoses. The illustration of the relations in assessment of potential impact factors/outcome associations used in multivariable analysis is shown in Supplemental Figure S1 in the Appendix.

Age-adjusted rates. We empirically estimated disease-specific mortality, hospital admissions, and ED visits in these groups for the 2007-2013 period. All-cause, infant mortality, and outcomes of anemia, kidney disease, tuberculosis, septicemia, and LBW infants (see Appendix for respective ICD codes) were studied as the health indicators, with disease-specific mortality as primary outcome. The main predictor was the presence of a hog CAFO in a given zip code. Analyses were performed for underlying cause of death/primary diagnosis and for underlying-plus-secondary causes of death/primary-plus-secondary diagnoses. The illustration of the relations in assessment of potential impact factors/outcome associations used in multivariable analysis is shown in Supplemental Figure S1 in the Appendix.

APPENDIX 1. The International Classification of Diseases (ICD) codes used in the analysis

This appendix is available in its entirety in the online edition of the NCMJ.
specific, age-adjusted rates of mortality, hospital admission, and ED visits (per 100,000). 95% confidence intervals (CIs) were estimated based on the approximation suggested by Keyfitz [35]. We compared these rates between Study groups 1 and 2 and the Control group, and additionally to North Carolina and the US average (for mortality rates).

**Logistic regression analysis.** We used logistic regression analysis (adjusted by age, median household income, education, health insurance coverage, numbers of primary care providers, and smoking prevalence) to evaluate whether a proportion of disease-specific deaths (as well as a proportion of disease-specific hospital admissions and ED visits) among all-cause deaths/all hospital admissions/all ED visits statistically differed between the studied groups. The Control group was a referent group for calculating ORs. This analysis allowed for minimization of potential bias due to uncertainties in population counts in North Carolina zip codes over the study period. SAS Proc Logistic (the SAS 9.4 statistical package; SAS Institute, Cary, NC) was used to evaluate ORs, 95% CIs, and p-values.

**The DiSC analysis.** We developed and applied an approach we termed the Distance from the Source of potential Contamination (DiSC) analysis to investigate the changes in ORs for all studied health outcomes with closer proximity to the CAFO. The core of this analysis is the new zip-code-specific continuous measure of potential exposures from hog CAFOs constructed using the exact address of each CAFO and the population counts in all census blocks in each zip code. We hypothesized that the risk of mortality (or hospital admission or ED visit) is proportional to the number of hogs in a CAFO, maximal at the location of a CAFO, and decreases with remoteness from a CAFO according to two-dimensional normal distribution (ie, “bell-shaped” distribution) of potential contaminants. Its standard deviation $\sigma$ is the measure of the distance from the CAFO at which the level of potential contaminants drops 2-fold. The functional form is justified by the theory of diffusion from a point source [36]. The zip-code-specific measures of potential contaminants from CAFOs were modeled by summing the contributions of all census block groups in a given zip code:

$$E_s(\sigma) = \sum_i p_i \sum_j N_i f(d_{nj}, \sigma)$$

where $n$ enumerates all CAFOs; $N_i$ is the number of hogs in the CAFO $n$; $i$ enumerates all census block groups in a zip code $i$; $p_i$ is population of census block group $j$ in zip-code $i$; and $N_i f(d_{nj}, \sigma)$, where $f(d_{nj}, \sigma) = \frac{1}{\sqrt{2\pi\sigma}} \exp\left(-\frac{d_{nj}^2}{2\sigma^2}\right)$ is the modeled contaminant level from a specific CAFO in a census block group (where $d_{nj}$ is the distance between them). Since there are no direct measurements that allow for estimating $\sigma$, we performed radius-specific analyses corresponding to 4 values of $\sigma$: i.e., at 2, 5, 10, and 20 kilometers (km). A zip-code-specific value of $E_s(\sigma)$ was then used in the logistic regression analysis to evaluate the associations with disease-specific outcomes in multivariable analysis. The evaluated ORs are per a unit of $E_s(\sigma)$. The OR estimates for different $\sigma$ are comparable because the measures are normalized equally: sums of contaminant levels over all zip-codes equal the total number of hogs in all CAFOs for any $\sigma$.

**Sensitivity analyses.** Because hog CAFOs are predominantly located in rural North Carolina, and access to medical care likely differs in urban and rural areas, we i) excluded zip codes of the cities of Charlotte and Raleigh, and also ii) excluded 18 urbanized areas defined in the US Census Bureau criteria for urban-rural areas as having $\geq 50,000$ residents.
We also used the generalized estimating equation (GEE) method to account for possible correlations between records in specific zip codes.

We used the greedy matching algorithm [37] to perform propensity score-based matching of zip codes from Control group to zip codes in Study group 2 by demographic and socioeconomic characteristics (see Appendix for detailed description of the matched groups and their characteristics presented in Table S1).

Ethics statement. All data analyses were designed and performed in accordance with the ethical standards of a responsible committee on human studies and with the Helsinki Declaration (of 1975, revised in 1983) and have been approved by the Duke University Health System Institutional Review Board.

Results

Demographic and socioeconomic characteristics. The residents of communities adjacent to hog farms were more diverse than the average North Carolina community. There were more African-American (28.8% vs. 19.3%, \(P < 0.001\)) and American-Indian (2.4% vs. 0.8%, \(P < 0.05\)) residents in zip codes with hog CAFOs (Study group 1) compared to the Control group (see Supplemental Tables S2 and S3 in Appendix). Study group 1 also had a lower median household income ($39,005 vs. $46,414, \(P < 0.001\)), fewer college-educated people with bachelor’s or higher degrees (16.5% vs. 24.2%, \(P < 0.001\)), and a lower number of primary care providers (54 vs. 76 per 100,000 residents, \(P < 0.001\)). The differences were even more pronounced for the residents of communities located in zip codes with > 215hogs/km² (Study group 2): 31.3% (\(P < 0.001\)) of the residents were African Americans and 41% were American Indians (\(P < 0.001\)). People from Study group 2 had the lowest (among the studied groups) median household income ($36,520, \(P < 0.001\)), percent of residents with bachelor’s or higher degrees (13.7%, \(P < 0.001\)), and number of primary care providers (51/100,000, \(P < 0.001\)) (see Supplemental Tables S2 and S3).

Mortality rates. Cause-specific mortality rates of all studied diseases were higher in North Carolina communities located in zip codes with > 215hogs/km² (Study group 2) compared to the North Carolina and US averages (see Table 1). The all-cause mortality rate in Study group 2 was as high as 934/100,000.

The residents from Study group 2 aged ≤ 24 years old had much higher all-cause mortality rates (92.7/100,000) than mortality rates in North Carolina (69.8/100,000) and the US (62.2/100,000) for this age group (see Table 1). Conditions originating in the perinatal period may have substantially contributed to the differences in mortality at younger ages; the mortality rate among infants under 1 year old in Study group 2 was as high as 495/100,000. This is much higher than both the US average (317/100,000) and the North Carolina average (398/100,000). The groups that contributed the most to increased mortality rates due to perinatal conditions were newborns affected by maternal trauma and by disorders related to length of gestation and fetal growth (see Table 1). The rates of infant death related to maternal trauma were much higher in North Carolina communities located in zip codes with > 215hogs/km² (149/100,000) than the United States and North Carolina averages. The rates of death related to the length of gestation and fetal growth were higher in both North Carolina (North Carolina average) and Study group 2 compared to the US average.

Patients from Study group 2 with multimorbid conditions such as co-existing septicemia and kidney disease, septicemia and anemia, or septicemia and kidney disease and anemia had mortality rates 1.5-2.2 times greater than North Carolina and 1.8-1.9 times greater than the US average mortality rates for patients with the same respective co-existing diseases (see Supplemental Figure S2 in Appendix).

For all studied diseases, the age-adjusted mortality rates were higher in Study group 1 than in the Control group, but lower than in Study group 2 (see Table 2), except for tuberculosis: its mortality did not significantly differ between Study groups 1 and 2.

To highlight the magnitude of higher mortality in the region, we modeled Study group 2 as an independent geo-

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**TABLE S1.** Characteristics of Matched Group A, Matched Group B, and Study Group 2, NC, 2007-2013

| Characteristic                  | Matched Group A | Matched Group B | Study Group 2 |
|--------------------------------|-----------------|-----------------|---------------|
| Percentage of African-American | 28.8%           | 24.2%           | 16.5%         |
| Percentage of American-Indian  | 2.4%            | 0.8%            | 0.8%          |
| Median household income ($)     | 39,005          | 46,414          | 31,3%         |

This table is available in its entirety in the online edition of the NCMJ.

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**TABLE S2.** Descriptive Table of the 3 Studied Groups of NC Communities with and without Hog Concentrated Feeding Animal Operations (CAFOs): Race-Specific Population Groups, Socioeconomic Characteristics, Smoking Prevalence, and Access-To-Care Characteristics, NC, 2007-2013

| Characteristic                  | Study Group 1 | Study Group 2 | Study Group 2 |
|--------------------------------|---------------|---------------|---------------|
| Percentage of African-American | 28.8%         | 41%           | 16.5%         |
| Percentage of American-Indian  | 2.4%          | 4.1%          | 0.8%          |
| Median household income ($)     | 39,005        | 46,414        | 31,3%         |

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graphic unit and compared its overall and disease-specific mortality rates to the US states with the highest mortality rates (see Supplemental Table S4 in Appendix). In this model, the geographic area encompassing Study group 2 would be ranked number 4 in the United States for the highest all-cause mortality, number 1 in the United States for mortality from anemia as underlying cause, number 1 for kidney disease, number 2 for septicemia, and number 3 for tuberculosis as underlying-plus-secondary cause.

The rates of hospital admissions and ED visits. For most of the studied diseases, the rates of hospital admissions and ED visits (see Table 2) were higher in Study group 1 than in the Control group, but lower than in Study group 2. Rates did not differ between Study groups 1 and 2 for anemia hospital admissions and ED visits (as primary diagnosis), ED visits for tuberculosis, and LBW hospital admissions (as primary-plus-secondary diagnosis); however, these rates were still higher than in the Control group.

**Logistic regression analysis.** After adjustment for 6 co-

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**TABLE 1.**

Age-Adjusted Mortality Rates (Per 100,000) in NC Communities with > 215hogs/km² (Study Group 2) Compared to the NC and US Average, 2007-2013. (95% Confidence Intervals are Shown in the Parentheses)

| Disease                              | Age and race group               | The US average¹ | The NC average¹ | NC communities with > 215hogs/km² |
|--------------------------------------|----------------------------------|-----------------|-----------------|----------------------------------|
| All-cause mortality                  | All ages, all races              | 750             | 803             | 934ᵃᵇ                           |
|                                      | (749.5-750.2)                   | (801.3-805.6)   | (922.7-944.8)   |                                  |
|                                      | White, all ages                  | 745             | 780             | 858ᵃᵇ                           |
|                                      | (744.5-745.2)                   | (777.9-782.6)   | (844.7-871.2)   |                                  |
|                                      | AA, all ages                     | 903             | 923             | 969ᵃᵇ                           |
|                                      | (901.6-904.1)                   | (917.4-928.4)   | (947.9-989.4)   |                                  |
|                                      | Age ≤ 24 years old, all races    | 62.2            | 69.8            | 92.7ᵃᵇ                          |
|                                      | (62.0-62.4)                     | (68.7-70.9)     | (86.3-99.1)     |                                  |
| Conditions of perinatal period       | All races, age < 1 year old      | 317             | 398ᵃᵇ           | 495ᵃᵇ                           |
|                                      | (314.4-318.6)                   | (381.1-408.5)   | (420.7-569.5)   |                                  |
| Newborns affected by maternal trauma | All races, age < 1 year old      | 74.6            | 102ᵃᵇ           | 149ᵃᵇ                           |
|                                      | (73.6-75.6)                     | (95.7-109.1)    | (110.6-195.3)   |                                  |
| Disorders related to length of       | All races, age < 1 year old      | 112             | 16³ᵇ           | 16³ᵇ                             |
| gestation and fetal growth           |                                  | (110.6-113.1)   | (154.8-171.8)   | (128.3-218.4)                    |
| Anemia (underlying cause)            | All races, all ages              | 1.5             | 1.9ᵃᵇ          | 2.6ᵃᵇ                           |
|                                      | (1.5-1.5)                       | (1.8-2.0)       | (2.1-3.2)       |                                  |
|                                      | AA, all ages                     | 3.0             | 3.6ᵃᵇ          | 5.3ᵃᵇ                           |
|                                      | (2.9-3.0)                       | (3.3-4.0)       | (3.9-7.1)       |                                  |
| Kidney disease (underlying cause)    | All races, all ages              | 14.6            | 18.³ᵇ          | 24.8ᵃᵇ                           |
|                                      | (14.5-14.6)                     | (18.0-18.6)     | (23.0-26.6)     |                                  |
|                                      | White, all ages                  | 13.³ᵇ           | 14.³ᵇ          | 18.³ᵇ                           |
|                                      | (13.3-13.4)                     | (14.5-15.2)     | (16.3-20.2)     |                                  |
|                                      | AA, all ages                     | 28.1            | 34.⁹ᵇ          | 37.⁷ᵇ                           |
|                                      | (27.9-28.3)                     | (33.8-36.0)     | (33.6-41.8)     |                                  |
| Tuberculosis (underlying + secondary | All races, all ages              | 0.31            | 0.30            | 0.6³ᵇ                           |
| cause)                               |                                  | (0.30-0.32)     | (0.26-0.35)     | (0.32-0.81)                      |
| Septicemia (underlying cause)        | All ages, all races              | 10.8            | 13.⁵ᵇ          | 16.⁶ᵃᵇ                           |
|                                      | (10.7-10.8)                     | (13.2-13.67)    | (15.1-18.1)     |                                  |

¹Mortality rates are obtained from the Centers for Disease Control and Prevention Multiple Cause of Death data (https://wonder.cdc.gov/mcd.html).
²African-American.
³Statistically significant difference compared to the US average.
⁴Statistically significant difference compared to NC average.

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**TABLE S4.**

Age-Adjusted Mortality Rates (Per 100,000) in NC Communities with > 215hogs/km² (Study Group 2): Ranks of This Area among the US States and District of Columbia with the Highest Mortality, 2007-2013. (95% Confidence Intervals Are Shown in the Parentheses)

This table is available in its entirety in the online edition of the NCMJ.

ᵃMortality rates were calculated using the Multiple Cause of Death data from the Centers for Disease Control and Prevention (https://wonder.cdc.gov/mcd.html).
DiSC analysis. After adjustment for 6 co-factors, the studied outcomes had similar distance-related patterns: the ORs were higher in close proximity to a hog CAFO than in more distant communities (see Table 4). For example, mortality ORs for kidney disease were the highest in communities located within 2 km of a CAFO (OR = 1.14, 95% CI: 1.10-1.19), and LBW (ED visits) (see Table 3).

**TABLE 2.** Age-Adjusted Rates (per 100,000) of Mortality, Hospital Admissions, and ED Visits in NC Communities with Hog CAFOs (Study Group 1), NC Communities with > 215hogs/km² (Study Group 2), and NC Communities without Hog CAFOs (Control Group), 2007-2013. Underlying Cause/Primary Diagnosis and Underlying-Plus-Secondary Cause/Primary-Plus-Secondary Diagnosis. (95% Confidence Intervals Are Shown in the Parentheses)

| Outcome                  | Disease                      | Underlying cause/Primary diagnosis | Underlying+secondary cause/Primary+secondary diagnosis |
|-------------------------|------------------------------|-----------------------------------|-----------------------------------------------------|
|                         | Study group 1                | Study group 2                      | Control group                                        | Study group 1                | Study group 2                      | Control group                                        |
| Mortality               | All-cause mortality          | 866a (861.1-870.0)                | 934a (922.7-944.8)                                  | 773 (770.4-775.2)            | 866a (861.1-870.0)                | 934a (922.7-944.8)                                  | 773 (770.4-775.2)            |
|                         | Anemia                       | 2.3a (2.1-2.6)                    | 2.6a (2.1-3.2)                                      | 1.7 (1.6-1.8)                | 28.4a (27.6-29.2)                | 35.5a (33.4-37.7)                                   | 17.0 (16.7-17.4)             |
|                         | Kidney disease               | 21.1a (20.4-21.8)                 | 24.8a (23.0-26.6)                                  | 17.1 (16.7-17.5)             | 101a (99.1-102.1)                | 119a (114.6-122.5)                                  | 75.4 (74.7-76.2)             |
|                         | Tuberculosis                 | 0.32a (0.21-0.42)                 | 0.24a (0.04-0.43)                                  | 0.13 (0.12-0.14)             | 0.52a (0.42-0.61)                | 0.63a (0.32-0.81)                                   | 0.23 (0.22-0.34)             |
|                         | Septicemia                   | 15.5a (14.9-16.1)                 | 16.6a (15.1-18.1)                                  | 12.7 (12.4-13.0)             | 67.9a (66.7-69.1)                | 75.1a (71.9-78.2)                                   | 50.9 (50.3-51.5)             |
| Hospital admissions     | Anemia                       | 112a (110.7-114.0)                | 113a (108.6-116.4)                                 | 87.4 (86.6-88.2)             | 1,989a (1,982-1,996)             | 2,179a (2,162-2,196)                                | 1,642 (1,638-1,645)           |
|                         | Kidney disease               | 164a (162.3-166.2)                | 187a (181.6-191.4)                                 | 128 (126.6-128.6)            | 1,809a (1,802-1,815)             | 2,031a (2,015-2,048)                                | 1,369 (1,366-1,372)           |
|                         | Tuberculosis                 | 1.8a (1.6-2.0)                    | 3.1a (2.4-3.7)                                      | 1.0 (0.9-1.1)                | 4.0a (3.7-4.3)                   | 6.2a (5.3-7.1)                                      | 2.4 (2.3-2.6)                |
|                         | Septicemia                   | 296a (293.6-298.8)                | 313.3a (306.7-319.5)                               | 239 (237.8-240.4)            | 437a (433.9-440.2)               | 468a (460.3-475.9)                                  | 344 (342.1-345.2)            |
| Low birth weight        | n/a                          | n/a                               | n/a                                                 | 2.2a (1.9-2.4)               | 2.5a (1.9-3.1)                   | 1.5 (1.4-1.6)                                       | 2.4 (2.3-2.6)                |
| ED visits               | Anemia                       | 84.8a (83.3-86.2)                 | 85.4a (81.9-88.9)                                  | 71.4 (70.6-72.1)             | 605a (600.8-608.4)               | 682a (672.2-691.7)                                  | 480 (478.1-481.9)            |
|                         | Kidney disease               | 26.4a (25.6-27.2)                 | 33.2a (31.3-35.3)                                  | 19.6 (19.2-20.0)             | 547a (543.4-550.5)               | 643a (634.0-652.3)                                  | 376 (373.9-377.2)            |
|                         | Tuberculosis                 | 0.22 (0.13-0.32)                  | 0.33 (0.12-0.53)                                    | 0.14 (0.11-0.14)             | 1.04a (0.8-1.13)                 | 1.42a (1.03-1.93)                                   | 0.72 (0.62-0.74)             |
|                         | Septicemia                   | 15.4a (14.8-16.0)                 | 20.1a (18.4-21.7)                                  | 13.7 (13.4-14.0)             | 26.2a (25.4-26.9)                | 35.4a (33.3-37.6)                                   | 21.1 (20.7-21.5)             |
| Low birth weight        | n/a                          | n/a                               | n/a                                                 | 3.0a (2.7-3.3)               | 4.7a (3.9-5.5)                   | 1.6 (1.5-1.7)                                       | 2.4 (2.3-2.6)                |

*aStatistically significant difference compared to the Control group.

*bStatistically significant difference compared to Study group 1.

n/a: non-applicable.
TABLE 3. Age-Adjusted Rates (per 100,000) of Mortality, Hospital Admissions, and ED Visits in NC Communities with Hog CAFOs (Study Group 1), NC Communities with > 215 hogs/km² (Study Group 2), and NC Communities without Hog CAFOs (Control Group), 2007-2013. Underlying Cause/Primary Diagnosis and Underlying-Plus-Secondary Cause/Primary-Plus-Secondary Cause/Primary-Plus-Secondary Cause/Primary-Plus-Secondary Cause. (95% Confidence Intervals Are Shown in the Parentheses)

| Outcome | Disease       | Underlying cause/Primary diagnosis | Underlying-+secondary cause/Primary-+secondary cause/Primary-+secondary cause/Primary-+secondary cause |
|---------|---------------|------------------------------------|-------------------------------------------------------------------------------------------------|
|         |               | Study group 1                      | Study group 2                                                                                   |
|         |               | (1.11-1.36), P = 0.0012            | (1.15-1.64), P = 0.0077                                                                      |
| Death   | Anemia        | 1.24                               | 1.39                                                                                              |
|         |                | (1.11-1.36), P = 0.0012            | (1.15-1.64), P = 0.0077                                                                      |
|         | Kidney disease | 1.13                               | 1.27                                                                                              |
|         |                | (1.09-1.17), P < 0.0001*           | (1.19-1.35), P < 0.0001*                                                                      |
|         | Tuberculosis   | 2.77*                              | 2.12                                                                                              |
|         |                | (2.33-3.21), P < 0.0001*           | (1.93-2.54), P < 0.0001*                                                                      |
|         | Septicemia     | 1.07                               | 1.08                                                                                              |
|         |                | (1.02-1.12), P = 0.0120            | (0.97-1.17), P = 0.1633                                                                       |
| Hospital | Anemia        | 1.07                               | 1.07                                                                                              |
| admissions|              | (1.05-1.09), P < 0.0001*           | (1.03-1.11), P = 0.0022                                                                       |
|         | Kidney disease | 1.09                               | 1.21                                                                                              |
|         |                | (1.07-1.11), P < 0.0001*           | (1.18-1.24), P < 0.0001*                                                                      |
|         | Tuberculosis   | 1.48                               | 2.81                                                                                              |
|         |                | (1.31-1.64), P < 0.0001*           | (2.54-3.08), P < 0.0001*                                                                      |
|         | Septicemia     | 1.03                               | 1.06                                                                                              |
|         |                | (1.02-1.04), P < 0.0001*           | (1.00-1.05), P = 0.0324                                                                       |
|         | LBW            | n/a                                | 1.44                                                                                              |
|         |                | (1.25-1.62), P = 0.0001*           | (1.04-1.76), P = 0.0661                                                                       |
|         | ED visits      | Anemia                             | 1.08                                                                                              |
|         |                | (1.02-1.04), P = 0.0001*           | (1.07-1.09), P = 0.0001*                                                                      |
|         | Kidney disease | 1.05                               | 1.26                                                                                              |
|         |                | (1.00-1.09), P = 0.0001*           | (1.18-1.34), P < 0.0001*                                                                      |
|         | Tuberculosis   | 1.38                               | 2.26                                                                                              |
|         |                | (0.84-1.93), P = 0.2451            | (1.33-3.19), P = 0.0868                                                                       |
|         | Septicemia     | 0.89                               | 0.82                                                                                              |
|         |                | (0.82-0.96), P = 0.0013            | (0.69-0.96), P = 0.0057                                                                       |
|         | LBW            | n/a                                | 1.53                                                                                              |

*Statistically significant difference between the Study groups 1 and 2.
#Remains significant under Bonferroni correction.
n/a, non-applicable.

without CAFOs (the results are presented in the Appendix, Table S5).

Discussion

We found that people living in southeastern North Carolina communities located near hog CAFOs had poorer outcomes for a variety of health conditions in different age groups than the residents of North Carolina communities located in zip codes without hog CAFOs; they had higher mortality due to infections, anemia, kidney disease, and perinatal conditions, and higher rates of hospital admissions and ED visits for LBW infants. The observed higher rate of all-cause mortality is consistent with the lower life expectancy in this area [1].

While the precise causes of higher anemia rates observed in our study are unclear, other studies have suggested that exposure to ammonia, hydrogen sulfide, methane, and particulate matters (PMs) near the CAFOs [23, 24], contamination of water and soil with zinc [25], exposure to the antibiotic chloramphenicol previously widely used to treat infections in hogs [26], and inappropriate human use of veterinary medications (certain NSAIDs or antibiotics) [38] cause anemia. Moreover, anemia is an independent risk factor of death in patients with chronic diseases [39, 40], a complication of renal failure [41] and tuberculosis [42], and a risk factor for preterm birth and LBW infants [43].

Earlier studies reported that workers in the swine

FIGURE S3.
Locations of Matched NC Zip Codes without Hog CAFOs (Matched Group A and Matched Group B) and Locations of Zip Codes with > 215hogs/km² (Study Group 2)

This figure is available in its entirety in the online edition of the NCMJ.
industry have a higher risk for tuberculosis; however, this disease has been recently eradicated from US livestock [44]. Our findings on higher rates of tuberculosis likely result from the impact of a combination of factors in this North Carolina region where co-existing medical and social determinants may exacerbate each other [6, 10]. While no information is currently available on potential risk of occurrence of antibiotic-resistant strains of Mycobacterium tuberculosis in the communities adjacent to hog CAFOs, this aspect may require detailed analysis. The increased risk of undiagnosed latent tuberculosis that may be present in these communities, which may have a higher number of foreign-born residents [45], also requires attention. Co-existence of factors that may promote tuberculosis from its latent to active form (eg, diabetes, immunosuppression, and other conditions) needs to be accounted for when developing a strategy for improving identification of latent and active cases (ie, through screening) and treatment adherence in patients who require therapy.

Higher mortality rates for infants living in North Carolina zip codes with > 215hogs/km² represent an important health issue for this population that requires the immediate attention of public health and health care specialists. Maternal trauma and the length of gestation and fetal growth contribute the most to infant mortality in these North Carolina communities and can be targeted by special programs on maternal and child health. Higher rates of LBW infants in North Carolina communities adjacent to hog CAFOs are an important parameter of maternal and child health, not only because of the immediate medical care needed for such infants, but also because of their increased lifetime risk of chronic diseases (eg, higher risk of development of diabetes mellitus, arterial hypertension, ischemic heart disease, depression, respiratory diseases, and chronic kidney disease) [46]. Targeted programs in North Carolina communities adjacent to hog CAFOs could provide information about health issues related to women’s and children’s health to women of childbearing potential,

### Table 4
The Distance from the Source of Potential Contamination (“DiSC”) Analysis: ORs of Mortality, Hospital Admissions, and ED Visits in NC Communities Located within Different Distances from Hog CAFOs: Underlying-Plus-Secondary Causes of Death/Primary-Plus-Secondary Diagnoses, Logistic Regression, Multivariable Analysis (Adjusted by Age, Income, Education, Health Insurance, Smoking, and Availability of Primary Care Providers), 2007-2013. (95% Confidence Intervals Are Shown in the Parentheses)

| Outcome       | Disease   | 2 km               | 5 km               | 10 km              | 20 km              |
|---------------|-----------|--------------------|--------------------|--------------------|--------------------|
| Death         | Anemia    | 1.11 (1.05-1.18)   | 1.05* (1.03-1.07)  | 1.04 (1.03-1.05)   | 1.03 (1.03-1.04)   |
|               | Kidney disease | 1.14 (1.11-1.18) | 1.06 (1.05-1.07)   | 1.03 (1.03-1.04)   | 1.02 (1.02-1.03)   |
|               | Tuberculosis | 1.37 (0.95-1.79)  | 1.12 (0.96-1.27)   | 1.09 (1.02-1.16)   | 1.07 (1.03-1.11)   |
|               | Septicemia | 1.11 (1.06-1.15)  | 1.04* (1.03-1.06)  | 1.03 (1.02-1.03)   | 1.02 (1.02-1.09)   |
| Hospital admissions | Anemia | 1.06 (0.91-1.07)  | 1.02* (1.01-1.03)  | 1.01 (1.01-1.02)   | 1.01 (1.01-1.03)   |
|               | Kidney disease | 1.22 (1.21-1.23) | 1.08* (1.08-1.09)  | 1.04* (1.04-1.04)  | 1.03* (1.03-1.03)  |
|               | Tuberculosis | 1.59 (1.44-1.75)  | 1.18 (1.13-1.24)   | 1.09 (1.06-1.12)   | 1.06 (1.04-1.07)   |
|               | Septicemia | 1.10 (1.08-1.11)  | 1.04* (1.03-1.04)  | 1.02 (1.02-1.02)   | 1.02 (1.01-1.02)   |
|               | LBW       | 1.21 (0.97-1.46)  | 1.06 (0.97-1.15)   | 1.04 (0.99-1.08)   | 1.03 (1.01-1.06)   |

| ED visits     | Anemia    | 1.15 (1.14-1.17)  | 1.05* (1.05-1.06)  | 1.03* (1.02-1.03)  | 1.02 (1.02-1.03)   |
|               | Kidney disease | 1.23 (1.21-1.24) | 1.08* (1.08-1.09)  | 1.04* (1.04-1.05)  | 1.03* (1.03-1.03)  |
|               | Tuberculosis | 1.99 (1.69-2.29)  | 1.30* (1.19-1.40)  | 1.13* (1.08-1.18)  | 1.07* (1.04-1.10)  |
|               | Septicemia | 1.14 (1.06-1.22)  | 1.06* (1.03-1.09)  | 1.03 (1.02-1.04)   | 1.02 (1.01-1.03)   |
|               | LBW       | 2.28 (2.12-2.44)  | 1.39* (1.34-1.45)  | 1.20* (1.17-1.22)  | 1.13* (1.11-1.14)  |

*Statistically significant difference from the value of the result at shorter vs. longer distances (eg, 5 km vs. 2 km, or 10 km vs. 5 km) within the same row in the table.
as well as supporting mothers and children from pregnancy through birth and beyond.

The DiSC analysis in our study highlighted a potential opportunity for associating residential and occupational exposures in communities located in close proximity to hog CAFOs; poorer health outcomes among the residents of communities located within 2-5 km from CAFOs could be due to additional exposures because of potential employment at CAFOs. That may provide some guidance as to the most efficient use of resources to screen and diagnose diseases/conditions found to be highly prevalent in these communities.

In this study we do not establish causality between exposures from hog CAFOs and higher risk of mortality, hospital admissions, or ED visits for studied diseases in communities adjacent to CAFOs. One interpretation of our findings could be that people who reside in such communities may simultaneously be affected by multiple risk factors including low income and education, higher smoking prevalence, and lower access to medical care. Nonetheless, after adjusting for such co-factors or comparing zip codes with similar co-factors, persistently poorer health outcomes were observed in the communities located in zip codes with hog CAFOs. Furthermore, the DiSC analysis demonstrated a higher risk of poorer health outcomes in closer proximity to the CAFO. Our sensitivity analysis showed that patterns of use of medical care among the residents of these North Carolina communities may also contribute to the differences in health outcomes. For example, residents of rural North Carolina areas (where most of the hog CAFOs are located) are more likely to use EDs when searching for medical assistance and less likely use hospitals (due to problems with access such as transportation issues, problems with medical insurance coverage, or behavioral patterns of preferring EDs to a staying in a hospital).

The limitations of this study include: i) a lack of individual measurements of exposure, co-factors, and potential biomarkers of exposure; ii) potential misclassification of exposure from spray fields, accounting for weather, season and wind direction, exposure to poultry facilities, and coal power plants; iii) limited list of population characteristics in currently available dataset to match the compared population groups; and iv) potentially different residential and occupational locations for the same person. Further studies must address these limitations. The problems of identifying potential causative agents and evaluation of dose-response relationships in hog CAFOs studies are discussed in the literature; it is difficult to account for all required factors in occupational health studies, but the detection of specific exposures and diseases in residential communities is even more challenging due to additional complexities caused by dispersion of environmental agents, different exposure pathways, and variability of individual susceptibility to contaminants [6].

Community based research has been gaining prominence as a source of information for medical decision-making. It has been recognized that detailed individual-level data on co-factors are rarely available in the US; therefore, opportunities for individual-level analyses that account for multiple risk factors are very limited. To obtain information on health outcomes in certain populations, public health specialists and policymakers have begun to shift their attention from an exclusive focus on individual-level studies toward community level analyses. When contributions of specific risk factors to health outcomes in communities can be evaluated, this information can be used for optimization of resource allocation for medical interventions designed to improve health outcomes [47].

Conclusion

Southeastern North Carolina communities located in close proximity to hog CAFOs are characterized by poor indicators of health that are not solely due to the impact of converging demographic, socioeconomic, behavioral, and access-to-care factors, but are also due to the additional impact of multiple hog CAFOs located in this area. Although causality with specific exposures from hog CAFOs was not established, our findings suggest research is needed in environmental factors that may influence these outcomes. In addition, these findings suggest an immediate need for improved screening, diagnosis, and intervention for conditions including infant mortality and LBW infants that were found to be overrepresented in these communities. Poor health outcomes in North Carolina communities adjacent to hog CAFOs may also need to be addressed by improving access to medical resources, and future studies to determine the contribution of factors that influence these outcomes are needed. NCMJ

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TABLE S5.
Age-Adjusted Cause-Specific Rates (per 100,000) of Mortality, Hospital Admissions, and ED Visits in Communities Located in Zip Codes with > 215 hogs/km² (Study Group 2) and in Communities Located in Zip Codes Matched by Percent of African Americans, Percent of Children and Adults Aged 65+ in Population, and Median Household Income (Matched Group A) and Additionally Matched by Percent of the Residents Aged 25+ with Bachelor or Higher Degree (Matched Group B), NC, 2007-2013. (95% Confidence Intervals Are Shown in the Parentheses)

| Disease Category | Study Group 2 | Matched Group A | Matched Group B |
|------------------|---------------|-----------------|-----------------|
| Mortality        |               |                 |                 |
| Hospital Admissions |             |                 |                 |
| ED Visits | |                 |                 |

This table is available in its entirety in the online edition of the NCMJ.

*Statistically significant difference when compared to Study group 2.
\(n/a\), non-applicable.
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## APPENDIX 1.
The International Classification of Diseases (ICD) Codes Used in the Analysis

| ICD-9 codes (used for analysis of HCUP data) | ICD-10 codes (used for analysis of Multiple Cause of Death data) |
|---------------------------------------------|---------------------------------------------------------------|
| 280-285 Anemia (includes Iron deficiency anemias, Other deficiency anemias, Hereditary hemolytic anemias, Acquired hemolytic anemias, Aplastic anemia and other bone marrow failure syndromes, Other and unspecified anemias) | D50-D53, D55-D59, D60-D64 Anemia (includes Nutritional anemias, Hemolytic anemias, Aplastic and other anemias and other bone marrow failure syndromes) |
| 580-589 Kidney disease (Nephritis, Nephrotic Syndrome, and Nephrosis) | N00-N19 Kidney disease (includes Glomerular diseases, Renal tubule-interstitial diseases, Acute kidney failure and chronic kidney disease) |
| 010-018 Tuberculosis | A15-A19 Tuberculosis |
| 038 Septicemia, 995.91 – Sepsis | A40, A41 Septicemia (includes Streptococcal sepsis, Other sepsis) |
| V21.3 Low birth weight | P07.1 Low birth weight newborn |
| | P00-P96 Conditions originating in perinatal period |
| | P00-P04 Newborns affected by maternal trauma |
| | P10-P15 Disorders related to length of gestation and fetal growth |
FIGURE S1.
Illustration of the Relations in the Assessment of Potential Impact Factors-Outcome Associations

The effect that requires interventions through targeted programs for environmental, educational, and other socioeconomic factors.

Exposure to hog CAFOs (presence of CAFOs, number of hogs, distance to the CAFO)

Demographic factors (age, race)

Access to medical care (number of primary care physicians, health insurance coverage)

Behavioral risk factors (smoking)

Socioeconomic characteristics (income, education)

Outcome: mortality
APPENDIX 3.
Sensitivity Analysis

2a) Proc Genmod was used for GEE analysis

2b) The propensity score for matching zip codes without CAFO to zip codes with > 215 hogs/km² (Study group 2) was evaluated using the percent of African Americans, percent of children and people aged 65+ among the residents, as well as median household income, and percent of people with a bachelor’s or higher degree. The greedy matching algorithm [37] was used to match zip codes with close propensity scores.

The Matched group A included 56 zip codes that were matched by using the percent of African Americans, percent of children (aged 0-19) and people aged 65+ among the residents, and median household income. The Matched group B included 55 zip codes matched by above listed characteristics of Matched group A and additionally by the percent of people with a bachelor’s or higher degree. Characteristics of matched zip codes (i.e., the results on balancing the variables in the matched groups) for the Matched group A and Matched group B are presented in Table S1.
Then, age-adjusted total mortality rate and cause-specific rates of mortality, hospital admissions, and ED visits were compared between Matched group A and B and Study group 2 for underlying cause of death or primary diagnosis and for underlying-plus-secondary cause of death or primary-plus-secondary diagnosis. As shown in Table S5, mortality rates for total mortality and anemia and kidney as underlying causes were higher in Study group 2 than in Matched group A and B. Also, mortality rates of anemia, kidney disease, tuberculosis, and septicemia were higher in Study group 2 than in both matched groups for these diseases as underlying-plus-secondary causes of death. Hospital admission and ED visit rates were higher in Study group 2 than in Matched group A and B for kidney disease and tuberculosis (for primary diagnoses and for primary-plus-secondary diagnoses). ED visits rate for children with LBW also was higher in Study group 2 than in both matched groups (for primary-plus-secondary diagnosis).
| Characteristics                                      | NC communities with hog CAFOs (Study group 1) | NC communities with >215 hogs/km² (Study group 2) | NC communities without hog CAFOs (Control group) |
|-----------------------------------------------------|----------------------------------------------|-------------------------------------------------|---------------------------------|
| Race (%)                                            |                                              |                                                 |                                               |
| White                                               | 63.9%**                                      | 58.3%**                                        | 73.7%                                      |
| African-American (AA)                               | 28.8%*                                       | 31.3%**                                        | 19.3%                                      |
| American Indian                                     | 2.4%*                                        | 4.1%**                                         | 0.8%                                       |
| Asian                                               | 0.8%**                                       | 0.3%**                                         | 2.5%                                       |
| Other                                               | 4.1%                                         | 6.0%**                                         | 3.7%                                       |
| Median household income                             | $39,005**                                    | $36,520**                                      | $46,414                                    |
| Bachelor or higher degree education                 | 16.5%**                                      | 13.7%**                                        | 24.2%                                      |
| Availability of primary care providers (per 100,000 population) | 54**                                         | 51**                                           | 76                                          |
| Percent of uninsured individuals                    | 18.2%                                        | 18.5%                                          | 17.8%                                      |
| Smokers prevalence among those aged 24+ years old   | 24.4%                                        | 25.9%**                                        | 24.0%                                      |

*P < 0.05. 
**P < 0.001.
### TABLE 53.
Person-Years of Observations in Race-Specific Groups of the Residents of NC Communities from the 3 Studied Groups, NC, 2007-2013

| Race               | NC communities with hog CAFOs (Study group 1) | NC communities with > 215 hogs/km² (Study group 2) | NC communities without hog CAFOs (Control group) |
|--------------------|-----------------------------------------------|---------------------------------------------------|--------------------------------------------------|
| White              | 10,054,073                                    | 1,588,477                                         | 36,675,276                                       |
| African-American (AA) | 4,528,375                                    | 851,839                                           | 9,593,021                                        |
| American Indian    | 370,901                                       | 111,226                                           | 411,900                                          |
| Asian              | 129,901                                       | 8,574                                             | 1,242,243                                        |
| Other              | 642,425                                       | 162,896                                           | 1,870,849                                        |
Appendix 7.

Figure S2. Mortality Rates among Patients with Co-Existing Anemia, Kidney Disease, and Septicemia: The US Average, NC Average, and NC Communities with > 215 hogs/km² (Study Group 2), 2007-2013. (95% Confidence Intervals Are Shown in the Parentheses)
TABLE 54.
Age-Adjusted Mortality Rates (per 100,000) in NC Communities with > 215 hogs/km² (Study Group 2): Ranks of This Area among the US States and District of Columbia with the Highest Mortality, 2007-2013. (95% Confidence Intervals Are Shown in the Parentheses)

| Disease, cause of mortality | NC communities with > 215 hogs/km² | Rank of the area with > 215 hogs/km² among the US states with the highest mortality | The US states (with their current respective ranks) with mortality rates closest to the rates of the area with > 215 hogs/km² |
|----------------------------|-----------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| All-cause mortality        | 934 (922.7-944.8)                 | #4                                                                                 | #3 Alabama 940 (936.7-943.1)                                                    |
| Anemia:                   |                                    |                                                                                    |                                                                                    |
| • as underlying cause,    | 2.6 (2.1-3.2)                     | #1                                                                                 | #1 Mississippi 2.3 (2.1-2.5)                                                    |
| • as underlying+secondary cause | 35.5 (33.4-37.7)              | #1                                                                                 | #1 West Virginia 24.4 (23.7-25.2)                                              |
| Kidney disease:           |                                    |                                                                                    |                                                                                    |
| • as underlying cause,    | 24.8 (23.0-26.6)                  | #2                                                                                 | #1 Louisiana 26.2 (25.7-26.8)                                                   |
| • as underlying+secondary cause | 119 (114.6-122.5)              | #1                                                                                 | #1 West Virginia 96.2 (94.7-97.7)                                              |
| Tuberculosis:             |                                    |                                                                                    |                                                                                    |
| • as underlying+secondary cause | 0.63 (0.32-0.81)               | #3                                                                                 | #2 District of Columbia 0.73 (0.49-1.04)                                         |
| Septicemia:               |                                    |                                                                                    |                                                                                    |
| • as underlying cause,    | 16.6 (15.1-18.1)                  | #7                                                                                 | #6 Alabama 17.0 (16.6-17.4)                                                    |
| • as underlying+secondary cause | 75.1 (71.9-78.2)              | #2                                                                                 | #1 District of Columbia 83.6 (80.7-86.4)                                         |

*Mortality rates were calculated using the Multiple Cause of Death data from the Centers for Disease Control and Prevention (https://wonder.cdc.gov/mcd.html).
FIGURE S3. Locations of Matched NC Zip Codes without Hog CAFOs (Matched Group A and Matched Group B) and Locations of Zip Codes with > 215 hogs/km² (Study Group 2).
### TABLE 55.
Age-Adjusted Cause-Specific Rates (per 100,000) of Mortality, Hospital Admissions, and ED Visits in Communities Located in Zip Codes with > 215hogs/km² (Study Group 2) and in Communities Located in Zip Codes Matched by Percent of African Americans, Percent of Children and Adults Aged 65+ in Population, and Median Household Income (Matched Group A) and Additionally Matched by Percent of the Residents Aged 25+ with Bachelor or Higher Degree (Matched Group B), NC, 2007-2013. (95% Confidence Intervals Are Shown in the Parentheses)

| Outcome | Disease | Underlying cause/Primary diagnosis | Underlying+secondary cause/ Primary+secondary diagnosis |
|---------|---------|----------------------------------|-----------------------------------------------------|
|         |         | Study group 2 | Matched group A | Matched group B | Study group 2 | Matched group A | Matched group B |
| **Mortality** | | | | | | | |
|         | Total mortality | 934 | (922.7-944.8) | 867* | (857.9-875.3) | 920* | (908.6-930.8) |
|         | Anemia | 2.65 | (2.2-3.2) | 2.1* | (1.6-2.5) | 1.8* | (1.3-2.2) | 35.5 | (33.4-37.7) | 20.6* | (19.2-21.9) | 24.1* | (22.3-25.9) |
|         | Kidney disease | 24.8 | (23.0-26.6) | 20.9* | (19.6-22.3) | 22.5* | (20.7-24.2) | 119 | (114.6-122.5) | 90.1* | (87.2-92.9) | 107* | (103.3-110.9) |
|         | Tuberculosis | 0.21 | (0.04-0.38) | 0.11 | (0.01-0.20) | 0.04* | (0.04-0.13) | 0.55 | (0.28-0.82) | 0.25* | (0.10-0.40) | 0.24* | (0.06-0.42) |
|         | Septicemia | 16.6 | (15.1-18.1) | 15.9 | (14.7-17.1) | 16.7 | (15.2-18.2) | 75.1 | (72.0-78.2) | 62.7* | (60.3-65.0) | 67.6* | (64.6-70.6) |
| **Hospital** | | | | | | | |
|         | Anemia | 113 | (108.6-116.4) | 116 | (112.3-118.6) | 141* | (136.3-145.3) | 2,179 | (2,162-2,196) | 1,867* | (1,854-1,880) | 2,165 | (2,148-2,183) |
|         | Kidney disease | 187 | (181.6-191.4) | 152* | (148.5-155.8) | 175* | (170.4-180.1) | 2,031 | (2,015-2,048) | 1,713* | (1,701-1,725) | 1,864* | (1,848-1,880) |
|         | Tuberculosis | 3.1 | (2.4-3.7) | 1.7* | (1.4-2.1) | 0.86* | (0.51-1.21) | 6.2 | (5.3-7.2) | 3.7* | (3.2-4.3) | 2.4* | (1.9-3.0) |
|         | Sepsis | 313.1 | (306.7-319.5) | 272* | (267.4-277.2) | 324* | (317.2-330.4) | 468 | (460.3-475.9) | 396* | (390.4-402.2) | 466 | (458.4-474.3) |
|         | Low birth weight | n/a | n/a | n/a | | 2.5 | (1.9-3.1) | 1.5* | (1.2-1.9) | 2.3 | (1.7-2.9) |
| **ED visits** | Anemia | 85.4 | (81.9-88.9) | 88.5 | (85.8-91.3) | 115* | (111.0-119.3) | 682 | (672.2-691.7) | 570* | (563.0-577.0) | 729* | (718.6-739.0) |
|         | Kidney disease | 33.2 | (31.1-35.3) | 25.1* | (23.6-26.6) | 31.7 | (29.6-33.8) | 643 | (634.0-652.3) | 517* | (510.7-524.2) | 633 | (623.7-642.3) |
|         | Tuberculosis | 0.32 | (0.11-0.53) | 0.15* | (0.04-0.25) | 0.08* | (0.03-0.18) | 1.4 | (1.0-1.9) | 0.89* | (0.62-1.17) | 0.61* | (0.32-0.90) |
|         | Sepsis | 20.1 | (18.5-21.7) | 12.1* | (11.1-13.2) | 21.3 | (19.6-23.0) | 35.5 | (33.3-37.6) | 20.1* | (18.7-21.4) | 33.1 | (31.0-35.2) |
|         | Low birth weight | n/a | n/a | n/a | | 4.7 | (3.9-5.5) | 1.04* | (0.74-1.34) | 1.9* | (1.4-2.5) |

*Statistically significant difference when compared to Study group 2.

n/a, non-applicable.