Neighborhood Socioeconomic Status and Influenza Hospitalizations Among Children: New Haven County, Connecticut, 2003–2010

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Objectives. We examined surveillance data for disparities in pediatric influenza-associated hospitalizations according to neighborhood socioeconomic status (SES) measures in New Haven County, Connecticut.

Methods. We geocoded influenza-associated hospitalization case data from the past 7 years for children from birth to age 17 years and linked these to US Census 2000 tract-level SES data. Following the methods of Harvard's Public Health Disparities Geocoding Project, we examined neighborhood SES variables, including measures of poverty and crowding. We calculated influenza-associated hospitalization incidence by influenza season and individual case characteristics, stratified by SES measures.

Results. Overall, the mean annual incidence of pediatric influenza-associated hospitalization in high-poverty and high-crowding census tracts was at least 3 times greater than that in low-poverty and low-crowding tracts. This disparity could not be fully explained by prevalence of underlying conditions or receipt of influenza vaccination.

Conclusions. Linkage of geocoded surveillance data and census information allows for ongoing monitoring of SES correlates of health and may help target interventions. Our analysis indicates a correlation between residence in impoverished or crowded neighborhoods and incidence of influenza-associated hospitalization among children in Connecticut. (*Am J Public Health.* 2011;101: 1785–1789. doi:10.2105/AJPH.2011.300224)

In the United States, influenza is a frequent cause of hospitalization for young children. Recent surveillance data indicate that the burden of pediatric influenza-associated hospitalization is between 10 and 30 cases per 100 000 population.[1] Many well-established risk factors exist for influenza complications in children, including age younger than 6 months, asthma, and other underlying medical conditions.[2] However, insufficient data exist on the relationship between socioeconomic status (SES) and severe influenza infections in children.

Few communicable disease surveillance systems currently capture individual SES data. In lieu of individual-level SES information, US Census data can be used to describe the socioeconomic conditions of the neighborhood in which an individual lives. Neighborhood affects health independently of personal socioeconomic and behavioral characteristics.[3–5] Moreover, studies have shown the value of geocoding and linking surveillance data to US Census data in describing the epidemiology of infectious and noninfectious diseases.[6–8]

Using population-based surveillance data from the Connecticut Emerging Infections Program, we investigated potential disparities in pediatric influenza-associated hospitalizations according to neighborhood SES measures.

METHODS

From 2003 to 2010, the Connecticut Emerging Infections Program conducted population-based surveillance for laboratory-confirmed, influenza-associated hospitalizations among children from birth to age 17 years. The surveillance catchment area was New Haven County, 1 of 8 counties in the state. According to US Census 2000 data, New Haven County had a pediatric population of approximately 200 000, of whom 64.6% were non-Hispanic White, 14.5% were non-Hispanic Black or African American, and 15.7% were Hispanic or Latino of any race. We collected surveillance data by medical record review, physician survey, and patient interview. Variables included demographic information, street address of residence, underlying conditions, and vaccination history in addition to influenza testing, treatment, and complications.[9] We geocoded home addresses of all cases using ArcGIS version 9.2 (ESRI, Redlands, CA) to identify the census tract (i.e., neighborhood) of residence.

Census Data

We obtained neighborhood SES data from the US Census 2000 Summary File 3. This data set contains household- and population-level information from the census's long form questionnaire.[10] From the Summary File 3, we examined 2 types of area-based SES measures: poverty and crowding. Census 2000 defined the poverty variable as the percentage of the population within a census tract for whom 1999 income was below the federally defined poverty level.[10] It defined crowding as the percentage of households within a census tract with more than 1 occupant per room.[10] We broke down neighborhood poverty into 4 levels: 0% to 4.9%, 5.0% to 9.9%, 10.0% to 19.9%, and 20.0% or higher.[8,11] We broke down neighborhood household crowding into 4 groups approximating quartiles in Connecticut: 0% to 0.9%, 1.0% to 2.9%, 3.0% to 4.9%, and 5% or higher.

We chose the percentage of the population living in poverty as a study variable both because it was recommended as a standard for area-based SES for routine analysis[8,11] and because it has been found to be a robust measure with high external validity.[12] We chose crowding for study because household and neighborhood crowding might be associated with influenza given its spread from person to person by the airborne route.[13,14] We examined both measures at the census tract level so that comparisons might be made across time, place, and population. Research has demonstrated that census tract–level measures may detect socioeconomic gradients more consistently than zip codes.[6,12]

Data Analysis

The methods for data analysis were based on those of Krieger et al.[8,15] and the Public Health Disparities Geocoding Project.[6,11] We linked census tract data from US Census 2000 to each geocoded influenza case record. We used US Census 2000 population data in the denominator for all incidence calculations. We used the χ^2 test for trend to test the significance of trends in incidence with increasing poverty or household crowding. We performed all statistical analyses in SAS version 9.1 (SAS Institute Inc, Cary, NC) or Epi Info version 3.3.2 (Centers for Disease Control and Prevention, Atlanta, GA).

RESULTS

For 7 influenza seasons, extending from October 2003 through April 2010, there were 527 cases of laboratory-confirmed, influenza-associated hospitalization among New Haven County children. A total of 517 (98%) of these cases were successfully geocoded. Pediatric influenza-associated hospitalization patients resided in 134 (72%) of the 185 populated census tracts within New Haven County.

Incidence of influenza-associated hospitalization was more than 4 times higher among children younger than 5 years than it was among older children (Table 1). Rates did not differ appreciably by gender; however, incidence did vary by race/ethnicity. Rates among Hispanic and Black children were 3.0 and 3.4 times higher, respectively, than they were among White children.

When examined by area-based SES measures, incidence of influenza-associated hospitalization showed a distinct gradient (Figure 1). As census tract poverty increased, the incidence of pediatric influenza-associated hospitalization progressively increased ($P<.001$, χ^2 for trend). A positive trend relationship was also evident for influenza-associated hospitalization and increased census tract household crowding ($P<.001$, χ^2 for trend). When we stratified the data by age group (<5 years vs 5–17 years), we found statistically significant positive trends for each neighborhood SES measure in both age groups ($P<.001$, χ^2 for trend). When we stratified data by race/ethnicity, we also found statistically significant positive trends for each neighborhood SES measure within each racial/ethnic group, with 1 exception: we found no significant association for neighborhood poverty among non-Hispanic Blacks in predicting influenza hospitalization. However, when we combined the 2 low-poverty groups and compared them with the combined total of the 2 high-poverty groups, we found an association for this group ($P=.03$).

When we further stratified data by season, including the 2009–2010 pandemic H1N1 season, the positive relationships between neighborhood poverty and influenza hospitalization and household crowding and influenza hospitalization remained and were present in each influenza season (Table 2). The relative rate of influenza-associated hospitalization in high-poverty vs low-poverty census tracts ranged from 2.2 in the 2008–2009 season to 8.0 in the 2003–2004 season. Likewise, the relative rate in high-crowding vs low-crowding census tracts ranged from 1.9 in the 2008–2009 season to 8.6 in the 2006–2007 season. The relationship between influenza hospitalization and area-based SES measures was statistically significant for each of the study seasons except for household crowding in the 2008–2009 season ($P=.05$, χ^2 for trend).

TABLE 1—Incidence of Influenza-Associated Hospitalizations Among Children: New Haven County, CT, 2003–2010

	Population	No. (%) of Cases	Incidence[a]
	Individual-level variables[b]		
Age, y			
<5	53 094	309 (60)	83.1
≥5	148 585	208 (40)	20.0
Gender			
Girls	98 311	243 (47)	35.3
Boys	103 368	274 (53)	37.9
Race/ethnicity[c]			
White (non-Hispanic)	130 235	192 (37)	21.1
Black (non-Hispanic)	29 329	147 (28)	71.6
Hispanic	31 657	138 (27)	62.3
	Neighborhood-level variables[d]		
Poverty level			
Low	94 414	131 (25)	19.8
Medium low	34 345	55 (11)	22.9
Medium high	35 358	144 (28)	58.2
High	37 113	187 (36)	72.0
Crowding			
Low	67 395	98 (19)	20.8
Medium low	67 914	116 (22)	24.4
Medium high	24 975	91 (18)	52.1
High	40 946	212 (41)	74.0

Note. The total sample size was 517.
[a]We calculated the average annual incidence per 100 000 person-years over all 7 study seasons.
[b]Population estimates for the individual-level variables come from Census 2000 Summary File 1.[16]
[c]Race/ethnicity data were missing for 40 (7.7%) cases.
[d]Population estimates for the neighborhood-level variables come from Census 2000 Summary File 3.[10] The US Census defines poverty as the percentage of the population within a census tract for whom 1999 income was below the federally defined poverty level.[10] It defines crowding as the percentage of households within a census tract with more than 1 occupant per room.[10] We broke down both variables into 4 levels. For poverty, we defined 0% to 4.9% as low, 5.0% to 9.9% as medium low, 10.0% to 19.9% as medium high, and 20.0% or above as high. For crowding, we defined 0% to 0.9% as low, 1% to 2.9% as medium low, 3% to 4.9% as medium high, and 5% or above as high.

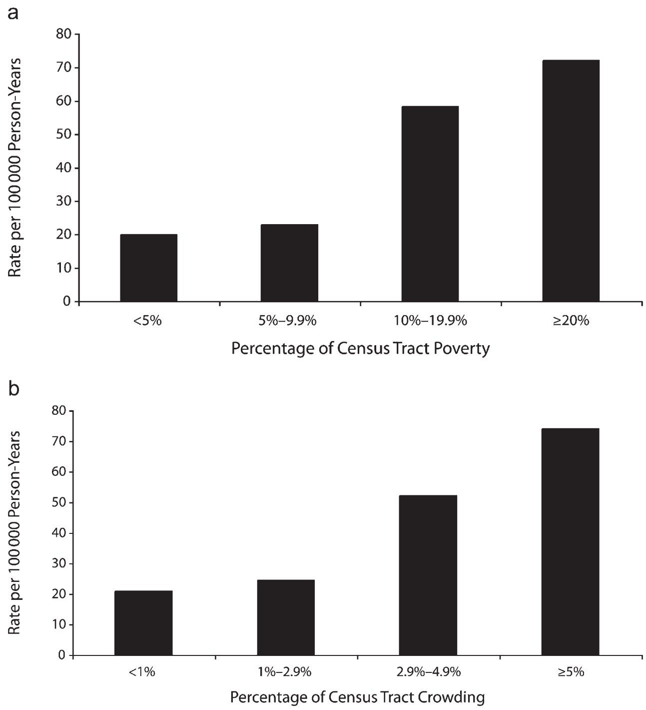

FIGURE 1—Mean annual incidence of pediatric influenza-associated hospitalization by (a) neighborhood poverty level and (b) neighborhood crowding level: New Haven County, CT, 2003–2010.

Table 3 presents the percentage of cases with each of 3 health status measures stratified by neighborhood poverty and crowding category. There was no trend in the percentage of cases with an underlying medical condition relevant to influenza infection or in the percentage of cases in which the individuals were vaccinated before hospitalization by increasing neighborhood poverty or crowding level. Within age groups, there was also no relationship between poverty level or crowding level and vaccination status. With increasing neighborhood poverty, the percentage of cases with underlying asthma rose slightly, from 19% in the census tracts with the least poverty to 28% in those with the most. However, this difference was not statistically significant (P=.2, χ^2 for trend with poverty exposure levels centered on their median value).

TABLE 2—Relative Rates of Pediatric Influenza–Associated Hospitalization, by Influenza Season: New Haven County, CT, 2003–2010

Season[a]	No.	High vs Low Poverty, RR	*P*	High vs Low Crowding, RR	*P*
2003–2004	96	8.0	<.001	4.9	<.001
2004–2005	91	3.4	<.001	3.1	<.001
2005–2006	58	2.3	.009	3.6	<.001
2006–2007	41	5.7	<.001	8.6	<.001
2007–2008	48	2.9	.001	2.6	.005
2008–2009	49	2.2	.037	1.9	.05
Pandemic H1N1 era	134	3.2	<.001	3.6	<.001

Note. RR = relative rate. We calculated relative rates for poverty by dividing the influenza-associated hospitalization incidence in highest-poverty tracts (poverty ≥ 20%) by that in the lowest-poverty tracts (poverty < 5%) for each influenza season. Likewise, for crowding, we calculated relative rates by dividing the influenza-associated hospitalization incidence in highest-crowding tracts (≥ 5%) by that in the lowest-crowding tracts (crowding < 1%). The *P* values (χ^2 for trend) are based on the gradient of all 4 poverty or crowding levels for each season.
[a]The influenza surveillance season extends from October 1 through April 30 each year except for the pandemic H1N1 era, which extended from April 15, 2009 through April 30, 2010.

DISCUSSION

By linking surveillance data with census tract information, it is possible to identify neighborhood characteristics associated with higher levels of disease burden. Similar analyses have been conducted for other health conditions.[6,12,17] However, this is the first time to our knowledge that pediatric laboratory-confirmed, influenza-associated hospitalization data have been examined in this way in the United States. These methods allow for direct examination of disparities by an SES measure, which is superior to surrogate SES measures, such as race, that can often produce results that are difficult to explain or lead to misunderstanding and stigmatization. Furthermore, these methods allow for a different perspective on intervention, which can be thought about in geographic and socioeconomic terms rather than in racial or ethnic terms.

This analysis indicates a correlation between residence in impoverished or crowded neighborhoods and incidence of influenza-associated hospitalization among children in New Haven County, Connecticut. Our data indicate that incidence of pediatric influenza-associated hospitalizations progressively increases as neighborhood poverty and neighborhood household crowding increase. This relationship can be demonstrated for each of the last 7 influenza seasons, including the 2009 H1N1 season. Furthermore, this relationship remains within strata defined by age and racial/ethnic group.

Persons in lower SES neighborhoods could be at higher risk for hospitalization with influenza for a number of possible reasons. First, crowding, both within households and within neighborhoods, increases the amount of close contact that is necessary for viral spread via

TABLE 3—Percentage of Pediatric Influenza–Associated Hospitalization Cases With Selected Characteristics, by Area-Based Socioeconomic Status Measures: New Haven County, CT, 2003–2010

	No. Cases	Underlying Condition,[a] No. (%)	Asthma, No. (%)	No. Cases With Available Vaccine Data	Received Influenza Vaccine, No. (%)
Poverty level					
Low	131	58 (44)	25 (19)	121	37 (31)
Medium low	55	25 (45)	13 (23)	46	11 (24)
Medium high	144	71 (49)	47 (33)	125	39 (31)
High	187	87 (47)	52 (28)	152	45 (30)
Crowding level					
Low	98	42 (43)	17 (17)	88	31 (35)
Medium low	116	57 (49)	31 (27)	107	31 (29)
Medium high	92	48 (52)	31 (34)	76	19 (25)
High	212	94 (44)	58 (27)	173	51 (29)

Note. The US Census defines poverty as the percentage of the population within a census tract for whom 1999 income was below the federally defined poverty level.[10] It defines crowding as the percentage of households within a census tract with more than 1 occupant per room.[10] Both variables were broken down into 4 levels. For poverty, we defined 0% to 4.9% as low, 5.0% to 9.9% as medium low, 10.0% to 19.9% as medium high, and 20.0% or above as high. For crowding, we defined 0% to 0.9% as low, 1% to 2.9% as medium low, 3% to 4.9% as medium high, and 5% or above as high.
[a]Underlying conditions may include any of the following: asthma, cystic fibrosis, other chronic lung disease, chronic cardiovascular disease, chronic metabolic disease, renal disease, hemoglobinopathy, neuromuscular disorder, immunosuppressive condition, seizure disorder, history of febrile seizures, prematurity (gestational age < 37 wk at birth for children < 2 y), developmental delay, pregnancy, long-term aspirin therapy, abnormality of the upper airway, obesity, and morbid obesity. Data were not collected for all of these conditions during all study seasons.

respiratory droplets. This increased contact may result in more influenza infections and more hospitalizations even if the rate of hospitalization per infection were constant across all neighborhood SES levels. Second, lower SES makes one less likely to have health insurance, which could negatively affect access to routine well-child care, including influenza vaccination and treatment of underlying conditions, such as asthma, that predispose those infected with influenza to require hospitalization.[18] Lower SES also increases the probability that care will be delayed, increasing the potential for preventable complications (e.g., severe exacerbation of asthma, pneumonia).[18] Third, asthma, an existing medical condition known to be linked to greater severity of influenza infections, is generally more common in persons living in the poorer and more crowded census tracts in our catchment area.[19]

We were able to explore a number of these possible reasons. We found no clear association between census tract poverty level and total number of underlying conditions, presence of underlying asthma, or vaccination status; therefore, the reasons for the differences by SES level cannot be fully explained by differences in these conditions in the New Haven County population. Additional investigation is needed to determine why incidence varies as a function of neighborhood SES.

Although possible differences in vaccination rates between lower- and higher-poverty neighborhoods did not fully explain our findings, annual vaccination for influenza is the most effective way to prevent infection and its associated complications.[2] Unfortunately, vaccination rates among children remain low. During the 2007–2008 flu season, 2 years after the Advisory Committee on Immunization Practices recommended vaccination for young children,[20] data from the National Immunization Survey indicated that only 55.1% of Connecticut children aged 6 to 23 months were at least partially vaccinated (i.e., received at least 1 of 2 recommended doses) and only 35.8% were fully vaccinated.[21] Vaccination rates of children younger than 5 years—who are most vulnerable to complications, and for whom vaccination was specifically recommended—were much higher than were those of older children.[22]

Since July 2009, the Advisory Committee on Immunization Practices has recommended annual influenza vaccination of all children aged 6 months and older.[22] There are serious logistical challenges to achieving this goal because it may overwhelm the basic pediatric care provider system.[23] If substantial influenza morbidity is to be prevented, however, it is critical that strategies—whether based in schools or communities—include special efforts to achieve high vaccination rates in higher-poverty neighborhoods, which have experienced increased rates of influenza-associated pediatric hospitalization. To eliminate disparities in influenza hospitalization, it is possible that higher immunization rates need to be achieved in poorer and more crowded neighborhoods than in less-poor and less-crowded ones.

Limitations

There are several important limitations to this analysis. First, because we used Census 2000 data for our neighborhood SES measures and denominators, both were 3 to 10 years out of date. Although we are not comparing rates across years, neighborhood composition can change over time.[24] Some census tracts may no longer be correctly categorized according to level of poverty and crowding. Similarly, incidence calculations may be inaccurate because of population movement into and out of census tracts that altered the denominator in our calculations. However, by design, census tracts are relatively standardized with regard to population characteristics. Furthermore, we minimized the impact of changes in individual neighborhoods by using aggregate data rather than individual census tracts. Thus, the impact of using older census data should be small.

Second, hospitalized influenza cases were reported from 9 different hospitals. Because these hospitals differ in the populations they serve and in the influenza screening methods they use, there could be bias in ascertainment of influenza-associated hospitalizations. It is notable that the largest hospital in the county, a hospital serving a substantial poor as well as more affluent suburban population, routinely screens all admissions with respiratory disease for influenza, whereas other area hospitals do not. Third, we measured influenza hospitalizations, not the incidence of influenza infection. Thus, these data cannot answer the question of whether persons living in poorer neighborhoods are more likely to get influenza infection or are more likely, once infected, to be hospitalized. Finally, we measured neighborhood SES, not individual SES. The findings should therefore be interpreted in this context and not as a surrogate for individual SES, which may have a separate influence on the incidence of hospitalization with influenza.

Conclusions

Children living in higher-poverty neighborhoods and neighborhoods with a higher rate of crowded living conditions have a higher incidence of hospitalization with influenza than do children in less-poor or less-crowded neighborhoods. Achieving high vaccination levels in such neighborhoods should be a key component of strategies to improve early childhood vaccination and to meet the recommendation to vaccinate all children annually. Analysis and monitoring of surveillance data using neighborhood SES measures can provide important data for planning and intervention that avoid some of the pitfalls of using race and ethnicity. ■

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Contributors

K.M. Yousey-Hindes contributed to study design, analyzed the data, and wrote the article. J.L. Hadler conceptualized the study, provided leadership during all stages of analysis and preparation, and reviewed and edited the article.

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Human Participant Protection

Surveillance for laboratory-confirmed influenza-associated hospitalization among children was deemed exempt from review by the institutional review boards at the CDC and Yale University.

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