Geographic Poverty and Racial/Ethnic Disparities in Cervical Cancer Precursor Rates in Connecticut, 2008–2009

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Objectives. We examined associations of geographic measures of poverty, race, ethnicity, and city status with rates of cervical intraepithelial neoplasia grade 2 or higher and adenocarcinoma in situ (CIN2+/AIS), known precursors to cervical cancer.

Methods. We identified 3937 cases of CIN2+/AIS among women aged 20 to 39 years in statewide surveillance data from Connecticut for 2008 to 2009. We geocoded cases to census tracts and used census data to calculate overall and age-specific rates. Poisson regression determined whether rates differed by geographic measures.

Results. The average annual rate of CIN2+/AIS was 417.6 per 100 000 women. Overall, higher rates of CIN2+/AIS were associated with higher levels of poverty and higher proportions of Black residents. Poverty was the strongest and most consistently associated measure. However, among women aged 20 to 24 years, we observed inverse associations between poverty and CIN2+/AIS rates.

Conclusions. Disparities in cervical cancer precursors exist for poverty and race, but these effects are age dependent. This information is necessary to monitor human papillomavirus vaccine impact and target vaccination strategies. (*Am J Public Health.* 2013;103:156–163. doi:10.2105/AJPH.2011.300447)

Genital human papillomavirus (HPV) is the most common sexually transmitted infection in the United States, with an estimated 6.2 million adolescents and young adults newly infected every year.[1] The prevalence of infection ranges from 27% to 45% among young women, and nearly 40% of women acquire HPV within 2 years of initiating sexual activity.[2–4] HPV is also an important public health problem because persistent infection with a high-risk HPV type is a necessary cause of cervical cancer.[5–7] Women living in poverty and racial/ethnic minorities continue to bear a disproportionate burden of cervical cancer incidence and mortality despite the decrease in rates that has resulted from widespread cervical cancer screening.[8,9] In 1998 to 2003, US incidence rates of invasive cervical cancer were 12.6 per 100 000 among Black women, 14.2 among Hispanics, and 8.4 among Whites; mortality rates showed similar disparities.[10] This pattern continued through 2007.[11] In a study from Massachusetts and Rhode Island, incidence rates in areas with 20% or higher and less than 5% of the population living in poverty were 17.6 and 9.2 per 100 000, respectively.[12] Data from a study in New York City revealed neighborhood poverty to be an important predictor of cervical cancer mortality.[13]

Precursors to cervical cancer are cervical intraepithelial neoplasia grades 2, 2/3, and 3 (CIN2+) and adenocarcinoma in situ (AIS). CIN2+/AIS diagnoses are an important public health problem not only because they are precursors to invasive disease, but also because they are common diagnoses that impose substantial health care costs and patient burden. Approximately 500 000 women are diagnosed each year with high-grade cervical disease, and these diagnoses account for annual health care costs of $450 million.[14–16] At the individual level, a diagnosis of CIN2+ results in an average of 7 to 8 office visits and 20 months of follow-up.[16] Many women also experience adverse psychological consequences following a diagnosis, such as fear of cancer, anxiety, distress, and concern about future fertility, along with medical procedures and difficulties with sexual relationships.[17] Disparities in precancerous lesions have not been directly examined, to the best of our knowledge. Data from 2 studies reveal noticeably higher rates of precancerous lesions among low-income women in a national screening program (4.6–7.4/1000 women) than among health plan enrollees (1.5/1000), who were likely of higher socioeconomic status[18,19]; however this is not a direct or precise comparison.

Since 2006, the Food and Drug Administration has approved 2 HPV vaccines that protect against 2 high-risk HPV types (HPV 16/18), which cause approximately 70% of cervical cancers. These vaccines have proven efficacy of 95% or higher in protecting against HPV 16/18–associated cervical lesions in HPV-naive women.[20,21] The Advisory Committee on Immunization Practices recommends routine use of either vaccine in a 3-dose regimen for girls aged 11 or 12 years and catch-up vaccination through age 26 years.[22] These vaccines have the potential to reduce disparities in cervical cancer. However, the extent to which this is realized will depend on high vaccine coverage for populations at greatest risk for outcomes associated with HPV infection. If vaccine coverage is not adequate and targeted, current disparities in cervical cancer may widen rather than narrow.

HPV vaccination programs may affect cervical cancer precursors and associated procedures within years rather than the decades it will take to measure impact on cervical cancer.[21,23–26] Therefore, determining the burden of cervical cancer precursors should be a public health priority because this information can be used to target vaccination strategies and provide a baseline for monitoring vaccine impact and disparities over time. We examined disparities in CIN2+/AIS rates in Connecticut, a state with mandatory reporting of these conditions, during prevaccine impact years 2008 to 2009, by geographic sociodemographic

measures of poverty, race, ethnicity, and city status. We chose the first 3 measures because they are the most commonly used indicators of disparities in cervical cancer.[8,10,12,13] We included a city measure because we hypothesized that disparities may exist along an urban gradient. Our results fill a key knowledge gap because few states mandate CIN2+/AIS reporting, and no statewide analysis of cervical cancer precursors and geographic measures has been reported.

METHODS

In 2008, the Centers for Disease Control and Prevention began to monitor the impact of HPV vaccination through population-based surveillance of CIN2+/AIS conducted by the Emerging Infections Program network. To facilitate implementation of this surveillance system in Connecticut, the Department of Public Health added CIN2+/AIS to the list of mandatory reportable diseases, effective January 1, 2008.[27] At the beginning of the reporting period, all 34 pathology laboratories in the state were contacted about the new reporting requirement. Reports contained diagnostic information as well as patient demographics, including residential address. All labs were regularly contacted to ensure ongoing, complete, and timely reporting, and audits were conducted at the 2 largest reporting laboratories. Reports were reviewed for eligibility and accuracy by trained staff, transcribed, and entered into a database. Quality assurance protocols included logic and range checks. To further ensure accuracy of data entry, a subset of cases (approximately one third of the total) underwent double data entry; erroneous entries were corrected in the database after confirming the correct element on the original pathology report.

We analyzed data from cases reported during January 1, 2008, through December 31, 2009. We included only women aged 20 to 39 years because they have the greatest burden of CIN2+/AIS, and rates were too low among younger and older women for statistically meaningful analysis. Because some women were reported multiple times during the study period, we removed duplicates from the data set and included only the first diagnosis of the highest-grade lesion for each woman.

Geocoding and Geographic Poverty, Race, and Ethnicity Measures

We geocoded cases to the census tract level, which has been shown to be appropriate for examining health disparities with US census data.[28] Census tracts are small, relatively permanent subdivisions of counties, are relatively homogeneous in population characteristics, and comprise approximately 4000 residents (typical range = 1000–8000).[29] We used 2000 US Census Summary File 3 data,[30] which contained 815 census tracts in Connecticut. Two census tracts had no residents, and 2 had no women aged 20 to 39 years, leaving 811 census tracts for analysis. We successfully geocoded 96% of reported cases (3937 of 4090) in women aged 20 to 39 years, in a 2-step process. First, we used ArcGIS version 9.2 software (ESRI, Redlands, CA). We considered an address successfully matched when the match score was at least 80. We then used the Federal Financial Institutions Examination Council Web site to manually match remaining valid addresses to census tracts.[31]

We modeled our methods and the choice of the geographic poverty measure on the Public Health Disparities Geocoding Project.[12,28,32] This project has developed and validated a methodologically rigorous approach for using geocoded public health surveillance data and geographic sociodemographic measures from US census data to describe health inequalities. We categorized poverty as the percentage of the population living below the federal poverty level,[33] as determined by family income, size, and composition. We determined race as the percentage of the population that was Black and ethnicity as the percentage of the population that was Hispanic. We examined each of these 3 measures with a priori established cutpoints of less than 5.0%, 5.0% to 9.9%, 10.0% to 19.9%, and 20% or higher. These cutpoints are recommended for the poverty measure in the Public Health Disparities Geocoding Project; we adopted them for the other measures after confirming that they produced adequate distributions for analysis (i.e., no category with < 30 census tracts, for meaningful analysis). We designated census tracts as city tracts if any part of the census tract lay within the municipal boundary of any of the 5 largest cities in Connecticut (each with a population > 100 000). To adjust our analyses for age, we calculated the proportion of the female population aged 20 to 39 years who were younger than 30 years for each census tract (i.e., larger proportions reflecting younger populations). Because no a priori cutpoints exist for this measure, we used quartile splits.

Statistical Analysis

We used population estimates from 2000 US census data to compute annual CIN2+/AIS rates. We estimated these rates by dividing the average annual number of geocoded cases during the 2-year surveillance period by the number of female residents in census tracts at each level of the 4 sociodemographic measures and age. We performed this calculation both overall and for each age group of interest: 20 to 24, 25 to 29, 30 to 34, and 35 to 39 years. We also estimated 95% confidence intervals. We used Poisson regression models to estimate unadjusted and adjusted rate ratios and 95% confidence intervals to determine whether statistically significant differences existed by levels of the geographic measures. The dependent variable in each model was the number of cases in each census tract, and we included population denominator offsets on the log scale to account for varying sizes of census tracts. We assessed unadjusted associations, with each measure entered individually in separate models. We entered all measures simultaneously into a full model to examine adjusted associations.

We ran 2 sets of models. First, we entered measures as nominal variables, with the lowest category as the referent group. This analysis allowed for varying associations between the different levels. In the second set of models, we entered measures as ordinal variables to detect any significant trends.

Our primary outcome was all CIN2+ diagnoses (CIN2, CIN2/3, CIN3) because CIN2 and CIN3 are both considered high-grade lesions and their clinical management is the same.[14] However, CIN2 lesions are more likely than CIN3 lesions to regress, meaning that CIN3 is a more immediate precursor to invasive cancer, and limitations of including CIN2 with CIN3 as surrogate endpoints for cancer have been noted.[34] We therefore conducted a secondary analysis for CIN3/AIS only. We conducted all statistical analyses with

SAS version 9.1 (SAS Institute Inc, Cary, NC) and SPSS version 17.0 (SPSS Inc, Chicago, IL).

RESULTS

During 2008 to 2009, a total of 3937 cases of CIN2+/AIS among unique female Connecticut residents aged 20 to 39 years were reported and geocoded, for an average annual rate of 417.6 per 100 000 women. We observed significant trends of increasing rates of CIN2+/AIS associated with higher levels of poverty and proportions of Black residents (Table 1). In adjusted analyses, the rates of CIN2+/AIS were 35% higher among women living in census tracts with 20% or more of the population living in poverty than in tracts with under 5.0% poverty rates. The rates of CIN2+/AIS were 14% and 20% higher among women living in census tracts with 20% or more and 10.0% to 19.9% of the population Black, respectively, than in tracts with less than 5.0% Black populations. Adjusted results were not significant for Hispanic ethnicity or city measures.

Age-specific rates varied: average annual rates per 100 000 women were 806.3 for 20 to 24 years, 596.7 for 25 to 29 years, 299.8 for 30 to 34 years, and 158.1 for 35 to 39 years. Effects of census tract levels of poverty, race, ethnicity, and city status on rates of CIN2+/AIS differed by age group (Table 2, Figure 1). For women aged 20 to 24 years, significant inverse associations remained in the adjusted model for poverty and city designation ($P < .05$ for trend tests). Rates were 23% and 20% lower among women living in census tracts with 20% or more and 10.0% to 19.9% of the population living below the federal poverty level, respectively, than in tracts with less than 5% poverty. Rates were 21% lower among women living in city tracts than in noncity tracts.

For women aged 25 to 29 years, we observed mixed effects, with a significant positive association for poverty and a significant inverse association for Hispanic ethnicity ($P < .05$ for trend tests). Rates were 34% higher among women living in census tracts with 20% or more of the population living below the federal poverty level than in tracts with less than 5%

TABLE 1—Census Tract Distributions of Poverty, Race, Ethnicity, City Status, Age, and Cervical Intraepithelial Neoplasia Grade 2 or Higher and Adenocarcinoma In Situ Rates and Rate Ratios Among Women Aged 20–39 years: Connecticut, 2008–2009

	Census Tracts, No. (%)	Women Aged 20–39 Years, No. (%)	Average Annual Cases, No.	Annual Rate per 100 000 Female Population, No.	Unadjusted RR (95% CI)	Adjusted RR (95% CI)
Total	811	471 390	1968.5	417.6		
Proportion of the population living below federal poverty level						
< 5.0	528 (65.1)	291 278 (61.8)	1136.0	390.0	1.0** (Ref)	1.0** (Ref)
5.0–9.9	118 (14.5)	82 526 (17.5)	364.0	441.1	1.13*** (1.04, 1.23)	1.09 (0.98, 1.21)
10.0–19.9	79 (9.7)	53 023 (11.2)	240.0	452.6	1.16*** (1.05, 1.28)	1.15 (1.00, 1.32)
≥ 20.0	86 (10.6)	44 563 (9.5)	228.5	512.8	1.32† (1.19, 1.45)	1.35† (1.14, 1.59)
Proportion of the population Black						
< 5.0	488 (60.2)	266 445 (56.5)	1030.5	386.8	1.0** (Ref)	1.0** (Ref)
5.0–9.9	90 (11.1)	62 341 (13.2)	259.5	416.3	1.08 (0.98, 1.19)	1.02 (0.90, 1.15)
10.0–19.9	101 (12.5)	65 150 (13.8)	315.0	483.5	1.25† (1.14, 1.37)	1.20*** (1.05, 1.37)
≥ 20.0	132 (16.3)	77 454 (16.4)	363.5	469.3	1.21† (1.12, 1.32)	1.14 (0.99, 1.32)
Proportion of the population Hispanic						
< 5.0	475 (58.6)	257 298 (54.6)	996.5	387.3	1.0** (Ref)	1.0 (Ref)
5.0–9.9	110 (13.6)	73 097 (15.5)	344.0	470.6	1.22† (1.11, 1.33)	1.08 (0.97, 1.20)
10.0–19.9	81 (10.0)	53 309 (11.3)	223.0	418.3	1.08 (0.98, 1.20)	0.88 (0.77, 1.02)
≥ 20.0	145 (17.9)	87 686 (18.6)	405.0	461.9	1.19† (1.10, 1.29)	0.87 (0.74, 1.01)
City						
No	648 (79.9)	370 523 (78.6)	1504.0	405.9	1.0 (Ref)	1.0 (Ref)
Yes	163 (20.1)	100 867 (21.4)	464.5	460.5	1.13*** (1.05, 1.22)	0.99 (0.89, 1.09)
Proportion of female population aged 20–39 y that are < 30 y						
0–30.5 (Ref)	203 (25.0)	97 867 (20.8)	338.0	345.4	1.0** (Ref)	1.0 (Ref)
30.6–38.0	203 (25.0)	107 636 (22.8)	454.0	421.8	1.22† (1.11, 1.35)	1.20† (1.08, 1.32)
38.1–47.3	203 (25.0)	133 963 (28.4)	595.0	444.2	1.29† (1.17, 1.41)	1.18*** (1.06, 1.31)
≥ 47.4	202 (25.0)	131 924 (28.0)	581.5	440.8	1.28† (1.16, 1.40)	1.10 (0.97, 1.25)

Note. CI = confidence interval; RR = rate ratio. *Source*. 2000 US Census.[30]
Source. 2000 US Census.[30]
*$P < .05$; **$P < .05$ for linear trend test; ***$P < .01$; †$P < .001$ for comparison with referent category.

TABLE 2—Unadjusted and Adjusted Rate Ratios for Cervical Intraepithelial Neoplasia Grade 2 or Higher and Adenocarcinoma In Situ by Poverty, Race, Ethnicity, and City Status Stratified by Age: Connecticut, 2008–2009

	Women Aged 20–24 y		Women Aged 25–29 y		Women Aged 30–34 y		Women Aged 35–39 y	
	Unadjusted RR[a] (95% CI)	Adjusted RR[b] (95% CI)	Unadjusted RR[a] (95% CI)	Adjusted RR[b] (95% CI)	Unadjusted RR[a] (95% CI)	Adjusted RR[b] (95% CI)	Unadjusted RR[a] (95% CI)	Adjusted RR[b] (95% CI)
Proportion of the population living below federal poverty level								
< 5.0 (Ref)	1.0**	1.0**	1.0**	1.0**	1.0**	1.0**	1.0**	1.0
5.0–9.9	0.82*** (0.71, 0.94)	0.96 (0.81, 1.13)	1.04 (0.90, 1.20)	1.09 (0.92, 1.30)	1.24* (1.02, 1.50)	1.07 (0.85, 1.35)	1.26 (0.99, 1.61)	1.10 (0.82, 1.47)
10.0–19.9	0.64† (0.55, 0.75)	0.80* (0.64, 0.99)	1.07 (0.90, 1.27)	1.16 (0.91, 1.48)	1.57† (1.26, 1.94)	1.31 (0.96, 1.77)	1.26 (0.92, 1.71)	1.07 (0.70, 1.62)
≥ 20.0	0.61† (0.52, 0.73)	0.77* (0.59, 0.99)	1.24* (1.04, 1.47)	1.34* (1.01, 1.79)	1.90† (1.53, 2.36)	1.63*** (1.13, 2.34)	1.70† (1.26, 0.30)	1.58 (0.96, 2.58)
Proportion of the population Black								
< 5.0 (Ref)	1.0**	1.0	1.0	1.0	1.0**	1.0	1.0**	1.0**
5.0–9.9	0.54† (0.46, 0.63)	0.60† (0.49, 0.74)	1.10 (0.93, 1.29)	1.19 (0.97, 1.47)	1.25 (0.99, 1.56)	1.02 (0.77, 1.35)	1.38* (1.04, 1.83)	1.29 (0.91, 1.84)
10.0–19.9	0.76† (0.65, 0.88)	0.95 (0.76, 1.18)	1.07 (0.91, 1.25)	1.19 (0.94, 1.51)	1.63† (1.34, 1.98)	1.27 (0.95, 1.71)	1.52*** (1.17, 1.97)	1.51* (1.03, 2.22)
≥ 20.0	0.64† (0.56, 0.74)	0.95 (0.75, 1.21)	1.11 (0.96, 1.29)	1.13 (0.87, 1.47)	1.64† (1.36, 1.97)	1.16 (0.84, 1.61)	1.50*** (1.17, 0.92)	1.47 (0.97, 2.23)
Proportion of the population Hispanic								
< 5.0 (Ref)	1.0**	1.0	1.0	1.0**	1.0**	1.0	1.0**	1.0
5.0–9.9	0.82*** (0.71, 0.95)	1.08 (0.91, 1.29)	1.00 (0.85, 1.17)	0.85 (0.70, 1.03)	1.57† (1.30, 1.91)	1.36* (1.07, 1.73)	1.51† (1.18, 1.93)	1.21 (0.89, 1.65)
10.0–19.9	0.69† (0.58, 0.82)	0.90 (0.72, 1.13)	0.90 (0.76, 1.08)	0.71* (0.55, 0.90)	1.41*** (1.12, 1.77)	1.08 (0.79, 1.47)	1.28 (0.94, 1.73)	0.89 (0.58, 1.34)
≥ 20.0	0.65† (0.57, 0.75)	0.97 (0.76, 1.24)	1.06 (0.92, 1.22)	0.73* (0.56, 0.96)	1.67† (1.39, 2.00)	0.99 (0.71, 1.40)	1.39*** (1.09, 1.78)	0.81 (0.51, 1.27)
City								
No (Ref)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Yes	0.67† (0.59, 0.76)	0.79*** (0.67, 0.94)	1.12 (0.99,1.27)	1.09 (0.92, 1.30)	1.47† (1.25, 1.73)	1.06 (0.85, 1.32)	1.29* (1.04, 1.62)	0.95 (0.70, 1.29)

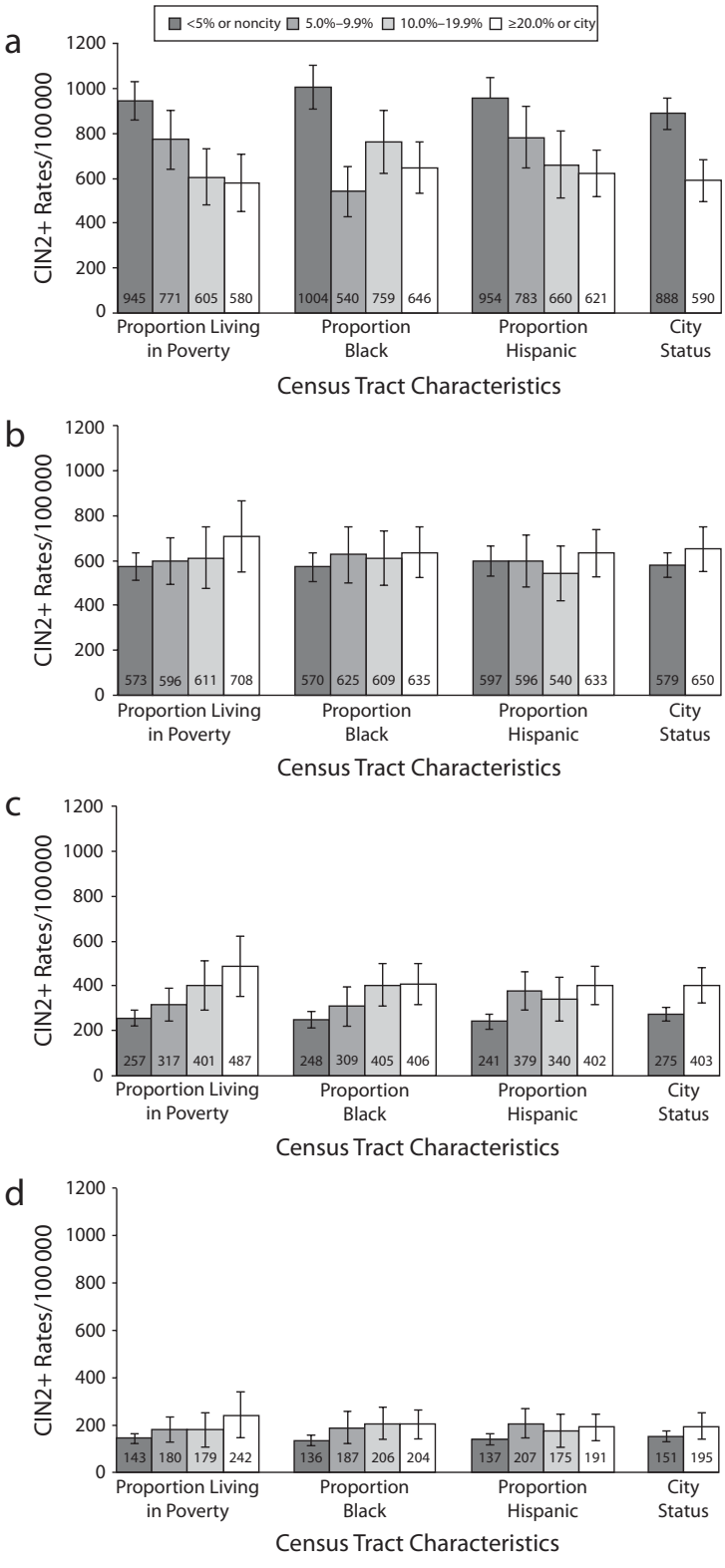
Note. CI = confidence interval; RR = rate ratio.
[a]From Poisson regression models with single measure entered.
[b]From full Poisson regression models with all measures in table entered.
*$P < .05$; **$P < .05$ for linear trend test; ***$P < .01$; †$P < .001$ for comparison with referent category.

poverty. Rates were 27% and 29% lower among women living in census tracts with 20% or more and 10.0% to 19.9% of the population Hispanic, respectively, than in tracts with populations that were less than 5% Hispanic. For women aged 30 to 34 years, a significant positive association remained in the adjusted model for poverty ($P < .05$ for trend test). Rates were 63% higher among women living in census tracts with 20% or more of the population living below the federal poverty level than in tracts with less than 5% poverty. Among women aged 35 to 39, the positive association remained significant for race, with rates 51% and 47% higher among women living in census tracts with 10.0% to 19.9% and 20% or more of the population Black, respectively, than in tracts that were under 5% Black. The effect for poverty in this age group, though nonsignificant, suggested a 58% higher rate among women living in census tracts with 20% or more of the population in poverty than in tracts with less than 5% poverty.

A total of 902 cases of CIN3/AIS were reported, for an average annual rate of 95.7 per 100 000 women. Age-specific rate estimates per 100 000 women also varied for CIN3/AIS: 135.3 for 20 to 24 years, 142.8 for 25 to 29 years, 84.1 for 25 to 29 years, and 49.5 for 35 to 29 years. Regression results for CIN3/AIS revealed patterns similar to results for CIN2+/AIS, although adjusted effects were generally not statistically significant (Table 3).

DISCUSSION

Our analysis revealed that women residing in census tracts with higher proportions of the population living in poverty and higher proportions of Black residents had significantly higher rates of CIN2+/AIS than did women in other tracts. Our observations of positive associations between area poverty and percentage Black with CIN2+/AIS suggest that women living in these areas will benefit from targeted HPV vaccination efforts. As a primary prevention method, vaccines that prevent acquisition of HPV, which can result in progression to CIN2+/AIS, could have an important public health impact, especially among those for whom cancer screening is suboptimal.



Note. Unadjusted rates per 100 000 female residents are in base of bars. Lines represent 95% confidence intervals.

FIGURE 1—Rates of CIN2+/AIS by poverty, race, ethnicity, and city status in women aged (a) 20–24 years, (b) 25–29 years, (c) 30–34 years, and (d) 35–39 years.

Our findings are consistent with a study of women with high-risk HPV types that reported significantly increased risk of CIN3 associated with decreasing years of education, a marker of socioeconomic status.[35] Together, these findings reinforce the notion that markers of socioeconomic status are salient factors for high-grade cervical disease. Findings regarding race/ethnicity are more mixed. A clinical trial in which all participants had equal access to care found a lower risk of CIN3 for Black and Hispanic than White, non-Hispanic women.[35] Other studies have shown no effect of ethnicity on risk of high-grade cervical lesions when consistent screening is provided.[36] Our results, derived from neighborhood-level measures and not controlled for access to care, showed a positive association with race but no consistent pattern or significant associations for ethnicity. Although these studies are not directly comparable because of different populations and methods, collectively they suggest that a complex interplay of socioeconomic status, race/ethnicity, and access to care affects rates of precancerous cervical lesions, diagnoses that are influenced not only by risk of acquiring HPV but also by screening behaviors.

Despite overall positive associations between poverty and CIN2+/AIS, we observed a strong inverse association for women aged 20 to 24 years, who had the highest rates of CIN2+/AIS, among those living in the lowest poverty category. This greater burden of disease may reflect increased detection rather than risk for HPV infection or disease progression. Many[37–40] but not all[41,42] studies show higher rates of cervical cancer screening with Papanicolaou tests (a necessary first step in detection of CIN2+/AIS) among higher-income populations, although the degree to which these differences are more pronounced for younger women is uncertain. If young women who are more affluent have higher CIN2+/AIS rates because of more screening and detection, this suggests that vaccination could have an early impact in this population on reducing diagnoses and associated costs, necessary treatment such as excisional procedures, sequelae associated with treatment such as risk for preterm labor, and anxiety associated with these diagnoses. In light of their relatively young ages (20–24 years) and the ages at which vaccination is recommended (11–26

TABLE 3—Rate Ratios for Cervical Intraepithelial Neoplasia Grade 3 and Adenocarcinoma In Situ by Poverty, Race, Ethnicity, and City Status Stratified by Age: Connecticut 2008–2009

	Women Aged 20–24 y		Women Aged 25–29 y		Women Aged 30–34 y		Women Aged 35–39 y	
	Unadjusted RR[a] (95% CI)	Adjusted RR[b] (95% CI)	Unadjusted RR[a] (95% CI)	Adjusted RR[b] (95% CI)	Unadjusted RR[a] (95% CI)	Adjusted RR[b] (95% CI)	Unadjusted RR[a] (95% CI)	Adjusted RR[b] (95% CI)
Proportion of the population living below federal poverty level								
< 5.0 (Ref)	1.0**	1.0	1.0	1.0	1.0	1.0	1.0	1.0
5.0–9.9	0.63 (0.44, 0.92)***	0.71 (0.46, 1.09)	0.95 (0.70, 1.29)	0.95 (0.67, 1.36)	0.90 (0.62, 1.33)	0.79 (0.50, 1.24)	1.36 (0.89, 2.07)	1.01 (0.61, 1.70)
10.0–19.9	0.65 (0.44, 0.95)***	0.75 (0.44, 1.28)	0.89 (0.62, 1.30)	0.89 (0.53, 1.48)	1.33 (0.88, 2.01)	1.20 (0.66, 2.16)	1.11 (0.62, 1.98)	0.81 (0.38, 1.73)
≥ 20.0	0.79 (0.54, 1.14)	0.90 (0.49, 1.67)	1.10 (0.76, 1.60)	1.01 (0.56, 1.83)	1.33 (0.85, 2.09)	1.21 (0.58, 2.53)	1.66 (0.96, 2.87)	1.30 (0.55, 3.10)
Proportion of the population Black								
< 5.0 (Ref)	1.0	1.0	1.0	1.0	1.0	1.0	1.0**	1.0
5.0–9.9	0.58 (0.39, 0.85)***	0.62 (0.38, 1.01)	1.04 (0.75, 1.46)	0.97 (0.64, 1.47)	1.45 (0.98, 2.14)	1.32 (0.82, 2.15)	1.57 (0.96, 2.57)	1.42 (0.76, 2.62)
10.0–19.9	0.78 (0.54, 1.12)	0.92 (0.53, 1.57)	0.91 (0.65, 1.27)	0.82 (0.51, 1.34)	1.23 (0.83, 1.83)	1.11 (0.63, 1.95)	2.05 (1.34, 3.14)***	1.85 (0.96, 3.57)
≥ 20.0	0.75 (0.54, 1.05)	0.97 (0.54, 1.75)	0.99 (0.73, 1.35)	0.85 (0.50, 1.46)	1.26 (0.87, 1.83)	1.04 (0.55, 1.96)	1.21 (0.74, 1.98)	1.07 (0.49, 2.32)
Proportion of the population Hispanic								
< 5.0 (Ref)	1.0**	1.0	1.0	1.0	1.0	1.0	1.0**	1.0
5.0–9.9	0.99 (0.71, 1.38)	1.32 (0.87, 2.01)	1.19 (0.87, 1.62)	1.26 (0.86, 1.83)	1.69 (1.20, 2.38)***	1.52 (0.99, 2.34)	1.63 (1.05, 2.52)*	1.29 (0.74, 2.26)
10.0–19.9	0.69 (0.44, 1.06)	0.94 (0.53, 1.67)	0.80 (0.54, 1.19)	0.90 (0.54, 1.51)	0.94 (0.58, 1.54)	0.83 (0.44, 1.55)	1.48 (0.88, 2.51)	1.07 (0.52, 2.23)
≥ 20.0	0.75 (0.54, 1.03)	0.99 (0.54, 1.81)	1.10 (0.82, 1.47)	1.24 (0.71, 2.15)	1.33 (0.93, 1.91)	1.04 (0.53, 2.02)	1.54 (1.00, 2.37)	1.11 (0.48, 2.53)
City								
No (Ref)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Yes	0.82 (0.61, 1.10)	0.89 (0.59, 1.34)	1.08 (0.83, 1.40)	1.11 (0.78, 1.59)	1.25 (0.91, 1.72)	1.12 (0.73, 1.71)	1.31 (0.88, 1.95)	1.01 (0.59, 1.70)

Note. CI = confidence interval; RR = rate ratio.
[a]From Poisson regression models with single measure entered.
[b]From full Poisson regression models with all measures in table entered.
*$P < .05$; **$P < .05$ for linear trend test; ***$P < .01$; †$P < .001$ for comparison with referent category.

years), it may be possible to observe vaccine impact for these women in the near future.

Our overall findings were generally strongest and most consistent and significant for the poverty measure. Thus, our findings add to a growing body of evidence that neighborhood poverty is a salient measure of socioeconomic inequalities in health disparities.[28,32,43] It is also further evidence of the pressing need for interventions for HPV vaccine programs that will reach women in low-income areas. The federal Vaccines For Children program, which provides free vaccine to providers treating low-income children through 18 years of age, can help with access and coverage.[44] Recent national data indicate that HPV vaccine initiation rates are comparable among Black, Hispanic, and White adolescents and higher among adolescents living below the poverty level than among their counterparts living at or above the poverty level[45]; these results are encouraging about the potential to vaccinate those in greatest need. However, access through Vaccines For Children may not be sufficient because low-income adolescents and racial/ethnic minorities likely face other cost and noncost barriers to initiation and completion of the 3-dose series.[46–49] Vaccinating younger adolescents prior to first sexual intercourse will have the greatest impact; however, vaccination resources may also be needed for low-income women still age eligible for HPV vaccination but not covered by the federal program, which is available only to those aged 18 years or younger. Because current coverage levels remain suboptimal (44% and 61% initiation rates in the United States and Connecticut, respectively[45]), additional public health interventions will be needed to increase uptake for populations disproportionately affected by CIN2+/AIS to have greatest impact on reducing disparities in cervical cancer precursors.

Our analysis served another key purpose: further demonstrating the utility of geocoding and of geographic measures in analyses of public health surveillance data. Geographic measures are increasingly recognized as important reflections of a complex combination of an area's composition, context, and location that can have independent effects on health.[12,28] This approach allowed us to analyze income and racial/ethnic disparities by linking case reports to readily available US

census data. This has been done for a variety of health conditions[12] as well as for other Emerging Infections Program projects[43,50] and is now an accepted and validated method for documenting and monitoring disparities, a necessary first step in addressing socioeconomic inequalities in health.

Limitations

We did not include individual-level measures for poverty, race, and ethnicity because these elements were often missing on the pathology reports that were collected for statewide surveillance (35% absent for insurance, 63% for race, and 91% for ethnicity). Although our intent was to assess contextual effects, we were not able to assess individual-level effects as well. Our goal was to use the pre–vaccine impact era as a baseline for monitoring future trends, but we cannot rule out some early vaccine impact in the surveillance period. However, we expect any impact to be minimal because the time between HPV infection and development of high-grade cervical lesions is often 2 to 5 years or longer.[51]

Our findings may not be generalizable beyond Connecticut. Relative to the United States, Connecticut has lower levels of poverty, smaller proportions of Black and Hispanic residents, and smaller urban areas.[52] Connecticut also has a slightly lower incidence of cervical cancer than in the United States as a whole.[53] Although these differences alone may not affect the observed associations, others are encouraged to explore these issues in their own locales where possible.

It is important to note that we did not have data on HPV types for all cases reported to statewide surveillance and that HPV types other than vaccine-preventable HPV 16/18 are often present in CIN2+/AIS (59% of CIN2/3 lesions tested positive for HPV 16/18 in a US meta-analysis[54]). Therefore, the potential impact of HPV vaccines cannot be fully estimated. Finally, the relatively small number of cases of CIN3/AIS (902 over 811 census tracts) yielded limited statistical power and may partially explain these nonsignificant findings. Nevertheless, a notable strength of our analysis was the statewide surveillance data with high case ascertainment, achieved through compliance of all pathology labs in the state with reporting requirements that limited selection bias and strengthened internal validity.

Conclusions

The recommended vaccines to prevent HPV infection have the potential to narrow disparities in cervical cancer. The degree to which this will occur depends on adequate and targeted vaccine uptake for those at greatest risk, namely, low-income women and racial/ethnic minorities. We present the first findings of geographic measures of poverty and racial disparities in CIN2+/AIS, precancerous cervical lesions that are common in the United States and are associated with substantial morbidity and costs. Our results demonstrate that vaccination efforts should be focused on low-income and minority women, who have the greatest burden of disease. Early impact of the vaccine may be observed among younger women residing in low-poverty areas with current high rates of detection. Future work is needed to better understand the associations between both individual and geographic measures and HPV vaccination rates and to overcome barriers among vulnerable populations so that effective vaccination programs can reduce known disparities in cervical cancer and its precursors. ■

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Contributors

L. M. Niccolai, P. J. Julian, J. I. Meek, J. L. Hadler, and L. Sosa conceptualized the study. P. J. Julian, A. Bliniski, and N. R. Mehta contributed to data collection, management, and geocoding. L. M. Niccolai performed the statistical analysis wrote the first draft of the article. D. Zelterman advised on the analytical plan. All authors interpreted results and read, commented on, and approved the final version of the article.

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Human Participant Protection

This study was deemed exempt from review by state and university institutional review boards because it was classified as public health surveillance.

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