

Assessing Influenza Vaccination Coverage Among An Urban Pediatric Asthma Population: A Geospatial Analysis

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Abstract

Background: Asthma is the most common chronic disease in children. Children with asthma are at high risk for complications from influenza; yet, annual influenza vaccination rates are suboptimal. The overall aim of this study was to describe the characteristics of a high-risk group of children with asthma according to influenza vaccination status.

Methods: The study was a retrospective chart review of 4355 patients aged 2 to 18 years evaluated in the pediatric emergency department (PED) between November 1, 2017 and April 30, 2018 with an ICD-10-CM code for asthma (J45.x). Eligible patient PED records were matched with influenza vaccination records for the 2017-2018 influenza season from the Michigan Care Improvement Registry. Geospatial analysis was employed to examine the distribution of influenza vaccination status.

Results: 1049 patients (30.9%) with asthma seen in the PED had received an influenza vaccine. Influenza vaccination coverage varied by Census Tract, ranging from 10% to >99%. Most vaccines were administered in a primary care setting (84.3%) and were covered by public insurance (76.8%). The influenza vaccination rate was lowest for children aged 5-11 (30.0%) years and vaccination status was associated with race ($p<0.001$) and insurance type ($p<0.001$).

Conclusions: Identification of neighborhood Census Tract and demographic groups with suboptimal influenza vaccination could guide development of targeted public health interventions to improve vaccination rates in high-risk patients. Given the morbidity and mortality associated with pediatric asthma, a data-driven approach may improve patient outcomes and reduce healthcare-associated costs.

Background

Asthma is the most common chronic disease in children, affecting approximately 5.5 million children under the age of eighteen in the United States ^[1]. Uncontrolled asthma, which affects approximately half of children, is associated with increased morbidity and mortality that disproportionately affects African American children and those living in poverty ^[2]. Many of these children seek care in the emergency department (ED), resulting in over half a million unscheduled ED visits per year for children under the age of 18 ^[3]. Given the significant health and economic burden associated with childhood asthma ^[3], it is a public health priority.

According to the Centers for Disease Control and Prevention (CDC) Advisory Committee on Immunization Practices (ACIP) and the American Academy of Pediatrics, children with asthma also constitute a high-risk population for complications from influenza ^[4,5]. Children with asthma account for over one-third of pediatric patients requiring intensive care for influenza associated complications, including pneumonia, respiratory failure, and death ^[6]. Therefore, vaccination is strongly recommended to help prevent severe influenza-related complications, particularly in children with asthma ^[7,8].

Despite ACIP recommendations, only 58% of children aged 6 months through 17 years received the influenza vaccine nationwide during the 2017-2018 season^[9]. Since the 2009 influenza pandemic, the 2017-2018 influenza season was considered one of the most severe^[10,11]. Reports of influenza-like illness were above season baseline levels for an extended period of time, resulting in a record number of pediatric deaths in comparison to a normal influenza season^[12]. In addition, trends for the 2017-2018 season showed a slight decrease in influenza vaccination coverage in younger age ranges when compared with the previous season^[9]. At the state level, the Michigan Department of Health and Human Services (MDHHS) reported lower vaccination coverage in the 2017-2018 season - the influenza vaccination rate for children was only 28.6% - while Wayne County was even lower at 27.0%^[13]. Influenza vaccination data for children with asthma is sparse. In the 2012-2013 influenza season, 55% of children with asthma were vaccinated with only 30% having received the vaccine early in the influenza season^[14]. Thus, concerted effort is needed for optimizing vaccine administration in children with asthma to reduce unexpected medically attended events.

Where a child resides plays a large role in determining their health status as it relates to racial, ethnic, cultural, and other socioeconomic factors^[15,16]. In Detroit, racial health disparities are even more pronounced due to the historical and structural factors of this urban population: an estimated 83% of individuals are African American and 40% of residents live below the poverty line^[17]. African American children are 2.5 times more likely to visit the ED for asthma and the prevalence of persistent asthma is 33% higher than in white children^[17]. Among this higher-risk group of children with asthma, racial disparities and cultural differences in vaccination coverage may mitigate vaccination, but the vaccination rate for this specific population is unknown^[18]. Understanding the geospatial distribution of vaccine uptake may provide important information on where to direct intervention efforts to improve vaccine uptake.

This study aimed to (1) describe the demographic and clinical characteristics of patients presenting to an urban pediatric emergency department (PED) with a history of asthma or for asthma-related symptoms according to influenza vaccination status during the 2017-2018 influenza season, (1.1) characterize influenza vaccination among an urban pediatric asthma population using geospatial analysis, and (2) describe differences in asthma and influenza characteristics according to patient age.

Methods

Study Setting, Design, and Participants

This retrospective study was conducted at an urban free-standing children's hospital located in Southeast Michigan with a Level 1 trauma center and over 85,000 PED visits annually. Records of patients aged 2 to 18 years evaluated in the PED between November 1, 2017 and April 30, 2018 and assigned an International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10-CM) diagnosis code for asthma (J45.x) at PED disposition were identified using Arbor Metrix. Arbor Metrix is an electronic

data repository for the Michigan Emergency Department Improvement Collaborative (MEDIC) [19]. The study dates were selected to reflect the peak influenza period for the 2017-2018 influenza season [12,20]. In order to include all children with asthma seeking PED care, patients with an ICD-10-CM code for asthma as the primary diagnosis or secondary diagnoses were included to reflect either an acute visit for asthma or a history of asthma [21]. To avoid including patients with a history of viral-induced wheeze, children < 2 years of age were excluded. Patients presenting to an affiliated satellite suburban PED or who resided outside of Michigan based on the registered home address in the electronic medical record (EMR) were also excluded.

Data Collection and Variables

Data obtained from MEDIC for eligible patients included demographic (age, gender), administrative (date of PED visit), and clinical (PED disposition) variables. The EMR was also reviewed by trained study personnel using a standardized data collection tool to abstract additional variables including: patient race or ethnicity, primary insurance type, home address, whether the patient presented for asthma symptoms (based on the treating PED clinician's diagnosis), whether the patient was diagnosed with influenza (based on the treating PED clinician's diagnosis), and whether influenza testing and results were documented. Influenza testing results were recorded if they were available in the EMR at any time during the patient's visit, such as testing obtained in the PED directly, documented from a prior clinic or ED visit, or performed during inpatient hospital admission.

Identified patient records were linked to the Michigan Care Improvement Registry (MCIR) to determine whether the patient had received an influenza vaccination at any point during the 2017-2018 season from September 1, 2017-April 30, 2018. MCIR collects immunization information from statewide providers and collates the information into a comprehensive immunization record-keeping system [22]. Date of vaccine administration, type of facility administering vaccine, and funding eligibility of vaccine administration were noted. Patients with no matching MCIR record were subsequently removed from the analysis because it was not possible to assess the vaccination status of these patients.

Definitions

As children less than 5 years of age are especially high risk for influenza complications [23], ages were grouped into the following ranges: 2-4 years (preschool), 5-11 years (school-aged), and 12-18 years (adolescence). Vaccine administration date was classified as "early" or "late" according to CDC guidelines, with "early" vaccination defined as influenza vaccine administered by October 31, 2017 [24]. For the purposes of this research, patient home addresses were initially grouped into three Statewide regions (Southeast, Central, and Western) according to county [25]. City of Detroit ZIP codes were categorized according to five neighborhood regions (East Riverfront, Northeast, Southwest, Westside, and Woodward Corridor) [26]. Data were aggregated and analyzed geospatially at the 2019 Census Tract boundary level within the City of Detroit. In health research, Census Tracts are regularly used as a default

for neighborhood ^[27]. Data were limited to Census Tracts in the City of Detroit due to the high level of patient density allowing for the low likelihood of identifying individual patient locations.

Data Analysis

General frequency and central tendency measures were performed to summarize descriptive statistics for patient characteristics. Statistical hypothesis tests were assessed for statistical significance using chi-square tests at a two-tailed alpha of 0.05. This test statistic was used to assess independence between vaccination status or age group and discrete factors. Analyses were performed using IBM SPSS Statistics, Version 25.0 (Armonk, NY: IBM Corp.). Hotspot analyses were run using Global Moran's I statistic and the Local Indicators of Spatial Autocorrelation (LISA) with GeoDa 1.18 software ^[28]. Moran's I and LISA were run in univariate hotspot analyses for vaccinated and unvaccinated patients as well as bivariate analyses accounting for socio-demographic characteristics of patients.

The Global Moran's I statistic for spatial autocorrelation was used to assess the correlation among neighboring observations and to identify patterns of spatial clustering ^[29]. The spatial weights were row-standardized and a spatial weight matrix was constructed that contained information on the demographic details for each Census Tract, including the Census Tract itself. Non-neighboring Census Tracts were assigned a weight of zero. Moran's I values range from -1 (dispersed) to +1 (clustered). A Moran's I value of 0 suggests complete spatial randomness. A random permutation procedure recalculates a statistic many times by reshuffling the data values among the Census Tracts to generate a reference distribution. The calculated statistic, based on the observed spatial pattern, is then compared to the reference distribution, and a pseudo significance level (pseudo *p* value) is computed. LISA provides information related to the location of spatial clusters and outliers and the types of spatial correlation. Local statistics are important because the magnitude of the spatial autocorrelation was not necessarily uniform over the study area ^[30,31]. This analysis used 999 permutations to determine the differences among the spatial units. A positive value for the local Moran's I index indicates that a feature has neighboring features that have similarly high or low attribute values, meaning that it is a part of a cluster. A negative value indicates that a feature has neighboring features that have dissimilar values, indicating that it is an outlier. In either circumstance, the *p* value for the feature must be small enough for the cluster or outlier to be considered statistically significant. LISA enables distinctions to be made among a statistically significant (0.05 level) cluster of high values (HH), a cluster of low values (LL), an outlier in which a high value is surrounded mostly by low values (HL), and an outlier in which a low value is surrounded mostly by high values (LH).

Results

The MEDIC data repository identified 4355 patient visits to the PED between November 1, 2017 and April 30, 2018. A total of 181 visits were excluded for the following reasons: presented to a satellite suburban PED, 44; resided out-of-state, 12; no matching MCIR record, 125. Among 4174 eligible patient visits, 3392 unique patients were identified and 1049 / 3392 (30.9%) received an influenza vaccine during the study

period. Overall, the majority of PED visits were by African Americans (80.7%), males (57.8%), children under 8 years of age (54.8%), and children with public or no insurance (83.0%). The median patient age for vaccinated and unvaccinated groups was 7 years (IQR 4.0-11.0). Overall, 23.9% of PED visits were associated with influenza testing. Of those with influenza testing, a positive influenza test result was documented at the time of the visit in 22.9% of encounters, with 83.4% of positive results due to influenza A. Additional demographic and clinical characteristics by vaccination status for the PED visit are reported in Table 1.

Table 1

Study population demographics and clinical characteristics according to vaccination status.

	Overall n = 4174 n (%)	Vaccinated n = 1323 n (%)	Unvaccinated n = 2851 n (%)	p-value
Gender	1761 (42.2)	548 (41.4)	1213 (42.5)	0.493
Female	2413 (57.8)	775 (58.6)	1638 (57.5)	
Male				
Age, years	1239 (29.7)	425 (32.1)	814 (28.6)	0.036
2-4	2008 (48.1)	602 (45.5)	1406 (49.3)	
5-11	927 (22.2)	296 (22.4)	631 (22.1)	
12-18				
Race	3 (0.1)	3 (0.2)	0	<0.001
American Indian/Alaska Native	12 (0.3)	6 (0.5)	6 (0.2)	
Asian	3369 (80.7)	970 (73.3)	2399 (84.1)	
Black/African American	273 (6.5)	109 (8.2)	164 (5.8)	
White	517 (12.4)	235 (17.8)	282 (9.9)	
Patient declined or unknown				
Ethnicity	179 (4.3)	81 (6.1)	98 (3.4)	<0.001
Hispanic/Latino	3995 (95.7)	1242 (93.9)	2753 (96.6)	
Not Hispanic/Latino				
Detroit Neighborhood (n=3069)	294 (9.6)	98 (10.5)	196 (9.2)	0.002
East Riverfront	803 (26.2)	251 (27.0)	552 (25.8)	
Northeast	319 (10.4)	122 (13.1)	197 (9.2)	
Southwest	1222 (39.8)	335 (36.0)	887 (41.5)	
Westside	431 (14.0)	124 (13.3)	307 (14.4)	
Woodward Corridor				

*Includes observation and inpatient hospital admissions.

	Overall n = 4174 n (%)	Vaccinated n = 1323 n (%)	Unvaccinated n = 2851 n (%)	p-value
Payer Type	711 (17.0)	247 (18.7)	464 (16.3)	<0.001
Private	3306 (79.2)	1047 (79.1)	2259 (79.2)	
Public	157 (3.8)	29 (2.2)	128 (4.5)	
No insurance				
PED Disposition	1066 (25.5)	364 (27.5)	702 (24.6)	0.072
Admission*	3067 (73.5)	943 (71.3)	2124 (74.5)	
Discharge	41 (1.0)	16 (1.2)	25 (0.9)	
Other				
Presenting for Asthma Symptoms	1753 (42.0)	532 (40.2)	1221 (42.8)	0.111
Yes	2421 (58.0)	791 (59.8)	1630 (57.2)	
No				
Influenza Test Documented	999 (23.9)	333 (25.2)	666 (23.4)	0.202
Yes	3175 (76.1)	990 (74.8)	2185 (76.6)	
No				
Influenza Test Result (n=999)	229 (22.9)	65 (19.5)	164 (24.6)	0.098
Positive	767 (76.8)	266 (79.9)	501 (75.2)	
Negative	3 (0.3)	2 (0.6)	1 (0.2)	
Unknown				
Influenza Type (n=229)	191 (83.4)	56 (86.2)	135 (82.3)	0.482
Influenza A positive	38 (16.6)	9 (13.8)	29 (17.7)	
Influenza B positive				

*Includes observation and inpatient hospital admissions.

The majority of PED visits were from patients residing in the Southeast region of the state (4161, 99.7%), with 11 visits (0.3%) from patients in the Central region, and 2 visits (<0.1%) from patients in the Western region. Most patients residing in the Southeast region of the state were living in the city of Detroit (2482 / 3392 patients, 73.2%). Within the city of Detroit, the relative majority of patients resided within the Westside neighborhood (40.0%), followed by Northeast (26.5%), Woodward Corridor (14.1%), Southwest

(10.7%), and East Riverfront (8.7%). As shown in Table 1, vaccination status varied by neighborhood: the greatest proportion of unvaccinated visits were by patients who lived in the Westside (41.5%). Within each neighborhood, the highest proportion of vaccinated patients lived in the Southwest (100 / 266, 37.6%), followed by East Riverfront (66 / 216, 30.6%), Northeast (201 / 658, 30.5%), Woodward Corridor (100 / 349, 28.7%), and Westside (270 / 993, 27.2%).

Among vaccinated patients (Table 2, n=1049), there were no notable differences in the timing of the vaccination with 49.1% receiving an “early” vaccine and 50.9% receiving a “late” vaccine. Most vaccines were administered in a primary care setting (84.3%) and through publicly funded campaigns (76.8%). The majority of vaccinated patients had received the influenza vaccine prior to the PED visit (n = 1047, 79.1%).

Table 2
Vaccine administration characteristics for vaccinated children, n (%) (n=1049).

Vaccine administration date*	515 (49.1)
Early	534 (50.9)
Late	
Location administering vaccine	884 (84.3)
Primary Care	81 (7.7)
Subspecialty or Other Clinic±	42 (4.0)
Hospital	23 (2.2)
Local Health Department	19 (1.8)
Pharmacy	
Vaccine administration publicly funded	806 (76.8)
Yes	243 (23.2)
No	
*Early vaccine administration date (September-October) and late vaccine administration date (November-April) determined according to CDC recommendations [24].	
±Includes vaccines administered at the following locations: Correctional clinic, Local health department satellite clinic, School-based health center, Specialty clinic, Teen health center.	

Although many visits captured patients with a history of asthma (58.0%), a greater proportion of unvaccinated patients were presenting to the PED for asthma-related symptoms (42.8% vs. 40.2%) and tested positive for influenza (24.6% vs. 19.5%). Among patients presenting to the PED for asthma related symptoms (n = 1753, 42.0%), only 30.3% (p-value 0.111) had received an influenza vaccination for the 2017-2018 season and 75.8% (p-value 0.013) of those vaccinated were vaccinated prior to the PED visit (data not shown). When stratified by age (Table 3), the proportion of PED visits for an acute asthma

exacerbation decreased with age, from 55.5% of visits among children aged 2-4 years to 24.9% of visits among children 12-18 years. Notably, a smaller proportion of visits for ages 5-11 (30.0%) were by children who had received the influenza vaccine. Over half of visits across all age groups were by children with late vaccine administration.

Table 3
Asthma and influenza characteristics by patient age groups.

	Age in years			p-value
	2-4	5-11	12-18	
Presenting for asthma exacerbation	688 (55.5)	834 (41.5)	231 (24.9)	<0.001
Yes	551 (44.5)	1174 (58.5)	696 (75.1)	
No				
Influenza case	80 (6.5)	127 (6.3)	28 (3.0)	<0.001
Yes	1159 (93.5)	1881 (93.7)	899 (97.0)	
No				
Influenza test documented	406 (32.8)	453 (22.6)	140 (15.1)	<0.001
Yes	833 (67.2)	1555 (77.4)	787 (84.9)	
No				
Influenza test result (n=999)	75 (18.5)	126 (27.8)	28 (20.0)	0.015
Positive	329 (81.0)	326 (72.0)	112 (80.0)	
Negative	2 (0.5)	1 (0.2)	0	
Unknown				
Vaccinated	425 (34.3)	602 (30.0)	296 (31.9)	0.036
Yes	814 (65.7)	1406 (70.0)	631 (68.1)	
No				
Vaccinated before PED visit (n=1323)	342 (80.5)	464 (77.1)	241 (81.4)	0.230
Yes	83 (19.5)	138 (22.9)	55 (18.6)	
No				
Vaccine administration date* (n=1049)	166 (49.6)	229 (48.9)	120 (48.8)	0.979
Early	169 (50.4)	239 (51.1)	126 (51.2)	
Late				
Reported by overall patient visits to the pediatric emergency department (PED) (n=4174) unless otherwise noted.				
*Early vaccine administration date (September-October) and late vaccine administration date (November-April) determined according to CDC recommendations [24].				

Additional analyses were performed by gender, race, and primary payer type. None of the analyses by gender were statistically significant. Conversely, whether the patient presented to the PED for asthma related symptoms (p-value <0.001), was diagnosed with influenza (p-value 0.023), received an influenza vaccination (p-value <0.001), or received an “early” influenza vaccine (p-value 0.008) were all statistically significant by racial group. Among PED visits for patients of African American race, a greater proportion presented to the PED for asthma-related symptoms (44.3%), were diagnosed with influenza (5.3%), were unvaccinated (71.2%), and received a “late” influenza vaccination (54.5%) than non-Hispanic white patients. Although not statistically significant (p-value 0.053), a smaller proportion of PED visits for African American patients were associated with influenza testing (23.2%). Finally, by primary payer type, both influenza testing documented at the time of the PED visit (p-value 0.021) and vaccination status (<0.001) were statistically significant. Although only a minority of PED visits were associated with influenza testing, 14.6% of those with no insurance had influenza testing documented in contrast to 24.6% of those with private insurance and 24.2% of those with public insurance. A greater proportion of visits with private insurance were associated with vaccination (34.7%) in contrast to visits with public (31.7%) or no insurance (18.5%).

Spatial analyses at the Census Tract level found high levels of clustering. Figure 1 displays the raw rate of influenza vaccination coverage by percentile by Census Tract in Detroit. Vaccination coverage among patients across Detroit ranged from a low of 10–100% in Census Tracts across the city. Vaccination coverage of <50% is particularly notable in the areas denoted in blue on Figure 1. There were significant degrees of clustering among vaccinated (Figure 2) and unvaccinated (Figure 3) patients with unvaccinated patients generating the greatest number of hotspots in the city.

The Global Moran’s I statistic (Table 4) identified two significant findings for spatial autocorrelation among unvaccinated patients: Black or African American race and being in the age 5 to 11 group. These two significant findings were also examined using LISA to pinpoint hotspots (Figure 4 and Figure 5).

Table 4
Results of statistical analyses of Global Moran's I measuring spatial autocorrelation

	Vaccinated		Unvaccinated	
	Moran's I	p-value*	Moran's I	p-value*
Flu Case	-0.015	0.306	-0.002	0.496
Asthma Exacerbation	0.024	0.178	0.052	0.046
White	0.048	0.041	-0.034	0.078
Black	-0.029	0.169	0.080	0.014
Ages 2 to 4	-0.009	0.405	0.028	0.151
Ages 5 to 11	0.039	0.094	0.070	0.017
Ages 12 to 18	0.019	0.219	0.031	0.124
*Indicates a pseudo p-value at permutation of 999				

Discussion

Vaccine administration is recommended to prevent severe influenza-related complications in pediatric patients with asthma. This study suggests suboptimal vaccination coverage, as seen during the 2017-2018 season, when less than one-third of asthma patients presenting to the PED had received an influenza vaccine. This is similar to the rate seen in another study in a minority population [32]. While influenza vaccination efforts may be hampered by factors such as age, race, and insurance status, our results highlight that vaccination rates vary substantially with Census Tracts. Geospatial analysis offers information that public health professionals can use to develop initiatives that will promote vaccine acceptance rates in higher risk communities.

Few previous studies have reported influenza vaccination rates for pediatric asthma patients, with reported vaccination coverage much higher than found in this research [14,33]. While our findings illustrate the limitations of applying national estimates to specific high-risk populations, both our data and national surveys indicate that only one-third of patients with asthma are vaccinated "early" (i.e., by end of October) in the influenza season. Earlier starts to the influenza season, as during 2017-2018, further underscore the importance of advocating for early vaccination. Vaccination does not immediately offer protection from influenza to a child [34]. Thus, to have the greatest benefit, it is important for vaccination to occur well before there is widespread influenza activity in the community. More than 50 percent of vaccinated children in our population received the influenza vaccine beyond recommended administration dates. Effective education and communication on the importance of receiving an influenza vaccine early in the season is merited and may be lacking for this high-risk population [35]. Amid the current pandemic of coronavirus disease 2019, interactions advocating for influenza vaccination may

be increasingly important ^[36], especially in pediatric groups where disparities in vaccination coverage are already known ^[37]. Expansion of mobile health technology in this urban setting may help reduce disparities and facilitate discussions for primary care health concerns ^[38,39].

The 2012 report “Improving Childhood Influenza Immunization: A Five Year Progress Report” published by the National Foundation for Infectious Diseases highlights action items for improving influenza vaccination coverage, including: provider education and recommendation for vaccination, providing tailored vaccine communication to address community needs, expanding vaccination opportunities to non-traditional settings, and encouraging vaccination to all members of the family ^[40]. Schools are a key setting where some of these strategies may be addressed; yet, the National Heart, Lung, and Blood Institute guide “Managing Asthma: A Guide for Schools” does not explicitly recommend that schools advocate for influenza vaccination ^[41]. School-based programs, including a student curriculum and a parental brochure, have been shown to be effective at shifting attitudes and motivating participants to receive recommended vaccines ^[42]. Additionally, prior to the start of influenza season, incorporation of influenza vaccine education into existing virtual ^[43] or school-based programs, such as the School-based Asthma, Allergy & Anaphylaxis Management Program (SA³MPROTM) and Step-Up Asthma, may be a beneficial approach for improving vaccine uptake ^[44–46]. Efforts can also be focused on children lacking insurance who may not be aware of eligibility to receive vaccines through programs such as Vaccines for Children ^[47]. Collectively, these interventions may be most impactful when delivered in schools or community health centers located in neighborhoods with low vaccination rates.

While primary care locations played a significant role in vaccinating children in this study, most patients in this population had not received the influenza vaccine. To ensure that any encounter with a healthcare professional during the influenza season is viewed as an opportunity to vaccinate, approaches to vaccination both inside and outside of the primary care setting (i.e., “non-traditional” options) should be considered ^[48]. Non-traditional options are particularly important in an urban setting where many children do not have an established relationship with a primary care provider ^[49–51]. Furthermore, a recent systematic review highlighted transportation as a common issue with accessing care but noted that transportation-only interventions may not be sufficient for improving health outcomes ^[52]. As improved health care access has been positively associated with influenza vaccination coverage, the opportunity to improve vaccine administration in non-traditional settings – such as at the hospital or pharmacy – may be an appealing alternative in an urban population ^[53,54]. Paired with education and communication interventions in schools and community health centers, “non-traditional” healthcare interactions serve as an added piece for building “reminder systems” in urban settings ^[32].

Studies have demonstrated patient acceptance of vaccination in the ED for Detroit adults ^[55] and cost effectiveness of offering the influenza vaccine in the PED ^[56], but most vaccinated patients in this study had received the influenza vaccine prior to the PED visit. However, approximately one-quarter of hospitalized children were unvaccinated. Hospitalization is an additional opportunity to vaccinate. One

study from a large children's hospital in Texas reported successfully improving vaccination rates among admitted children with asthma from 13.3–57.4%^[57]. In addition to ambulatory and inpatient initiatives, hospitals can also consider immunization centers, which, depending upon the needs of the community, may be tailored to non-traditional hours to further improve access^[58]. Outside of the hospital setting, only a minority of children in our study were vaccinated in a pharmacy. Underutilization of neighborhood pharmacies represents a missed opportunity to improve vaccination capacity as pharmacies have proven that they can play an integral role in community immunization initiatives^[59]. Finally, incorporating influenza vaccination into mobile asthma clinics may be an efficient way to target neighborhoods with lower rates of vaccination while eliminating transportation barriers to care.

Limitations

The retrospective nature of this study may undermine the accuracy of the data as analyses were limited by the information available in the EMR. Second, the context may be unique, and the findings noted herein may not be generalizable to other settings, i.e., different racial communities or non-urban areas and healthcare environments. Third, it is unknown whether the vaccination status of the patient correlated with the acuity of the PED visit, or the clinical context of care received during the PED visit. Finally, study findings are limited by insufficient information to determine whether the influenza vaccination for the 2017-2018 season was complete for any given individual. Records were not available from prior seasons to account for those patients who may have been receiving the vaccination for the first time as these patients would have required two doses during the included influenza season to be considered completely vaccinated.

Conclusions

Influenza vaccination among pediatric patients with asthma is suboptimal. Geospatial analysis can help highlight communities with a greater need for targeted public health interventions, which can further enable engagement of families, schools, hospitals, and health care providers, including pharmacies, within that neighborhood. More studies are needed to determine the efficacy of this data-driven approach to public health in improving influenza vaccine uptake in children with asthma. Yet, findings from this study may be used by public health professionals to inform community level interventions to educate and improve vaccination rates in preparation for future influenza and viral seasons.

Abbreviations

Emergency Department (ED)

Pediatric Emergency Department (PED)

Centers for Disease Control and Prevention (CDC)

Advisory Committee on Immunization Practices (ACIP)

Michigan Department of Health & Human Services (MDHHS)

Michigan Emergency Department Improvement Collaborative (MEDIC)

Electronic Medical Record (EMR)

International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10-CM)

Michigan Care Improvement Registry (MCIR)

Local Indicators of Spatial Autocorrelation (LISA)

Declarations

Ethics approval and consent to participate: Administrative permission to access the raw data from the Michigan Emergency Department Improvement Collaborative (MEDIC), an electronic data repository, was received from Wayne State University, and permission to access identified patient records in the Michigan Care Improvement Registry (MCIR) was received from the Michigan Department of Health and Human Services (MDHHS). The Institutional Review Boards of Wayne State University (111218MP2E) and the MDHHS (201901-05-EA) reviewed and approved the conduct of this study. A waiver of consent and assent applied due to the minimal risk and retrospective nature of the study.

Consent for publication: Not applicable.

Competing interests: The authors declare no competing interests.

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Authors' contributions: SP developed research design, conducted protocol, and reported research findings. AD developed research design and reviewed and supervised research implementation. AH conducted geospatial analysis. RA developed research design and coordinated electronic medical record data acquisition. JGC assisted with research design, partnerships, and manuscript development. All authors read and approved the final manuscript.

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Availability of data and materials: Administrative permission was required to access the raw data. Please see the Ethics and Consent to Participate section.

Code availability: Not applicable.

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Figures

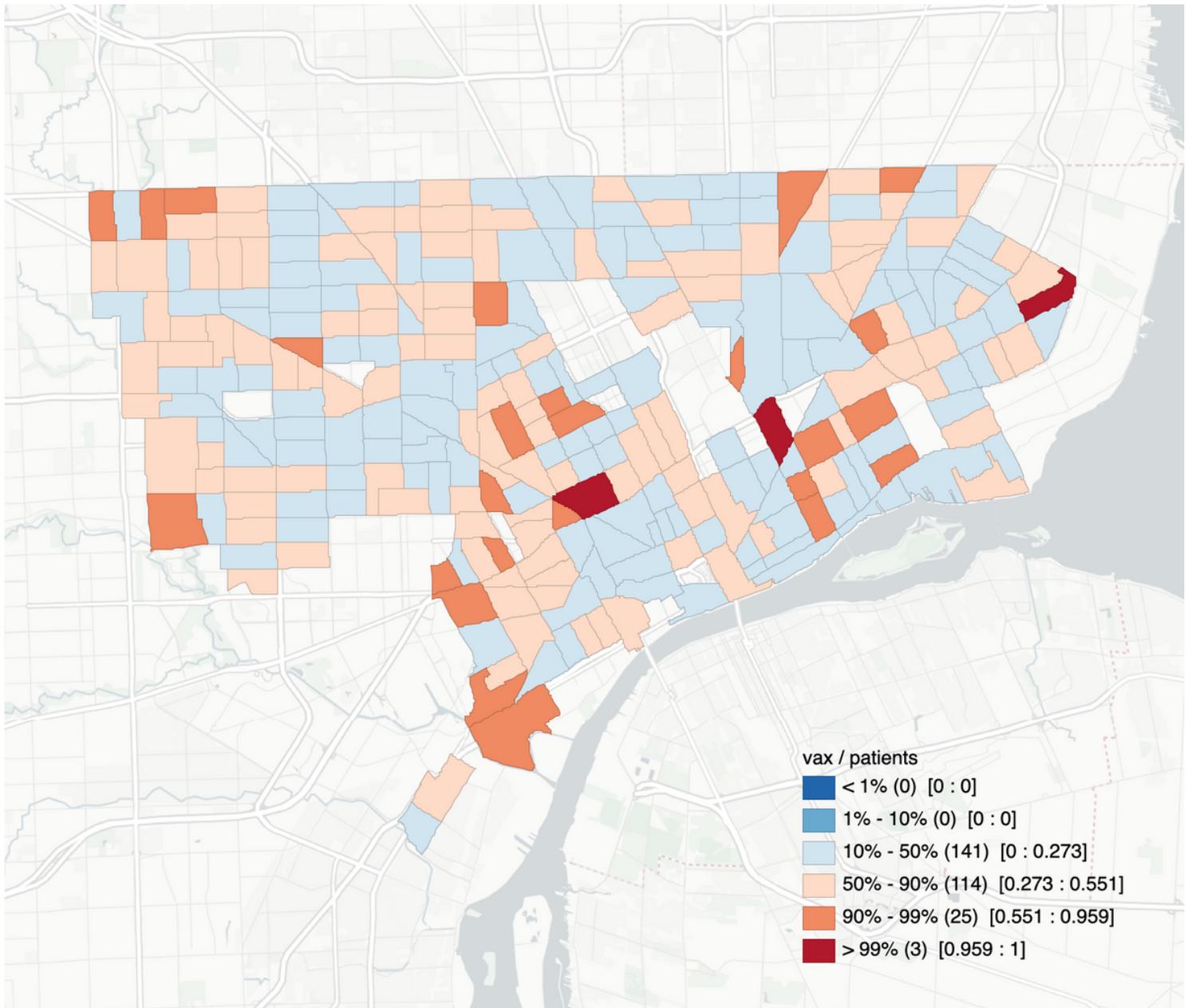


Figure 1

Influenza vaccination coverage percentiles by Census Tract in Detroit.

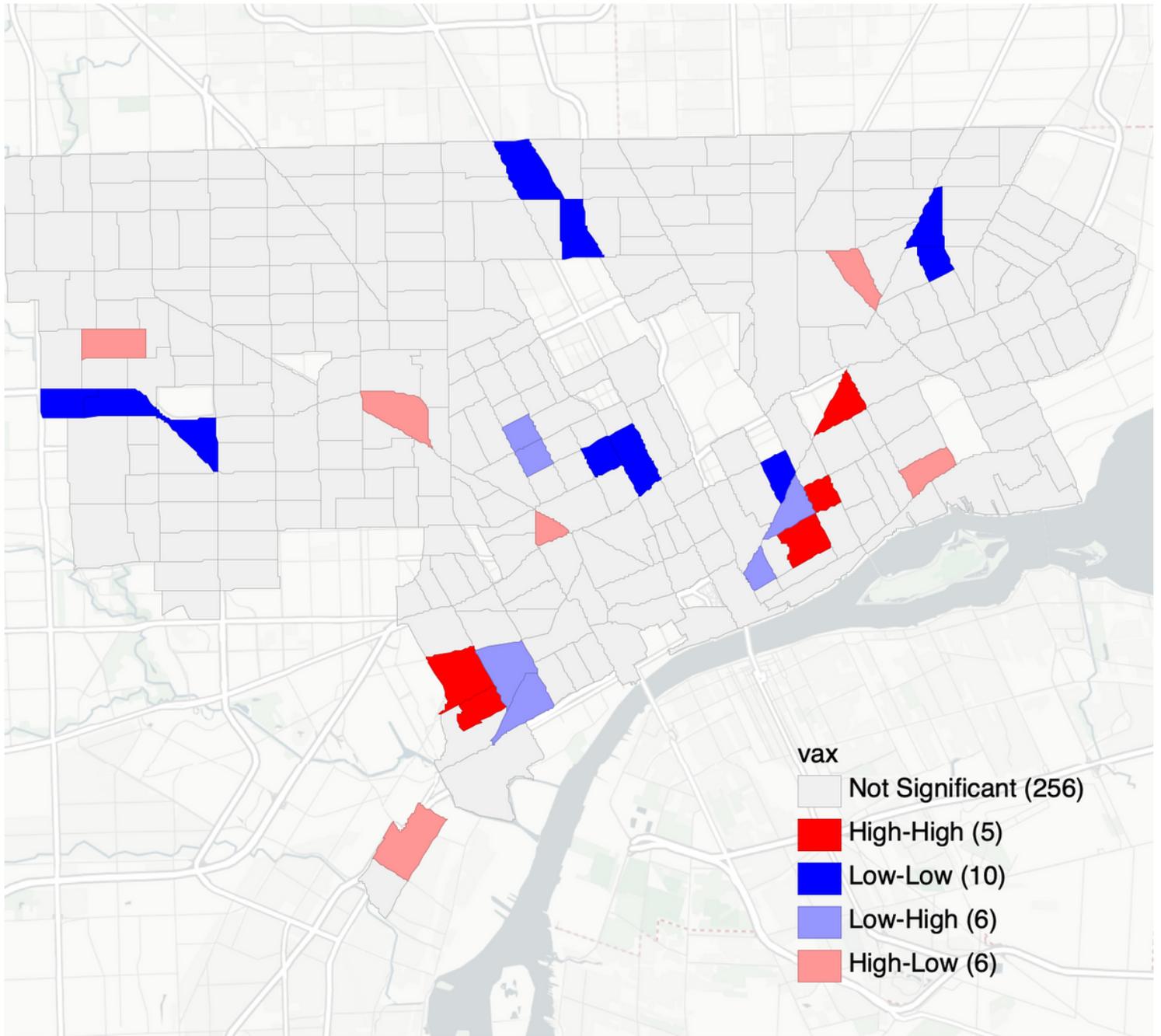


Figure 2

Hotspot clusters of vaccinated patients.

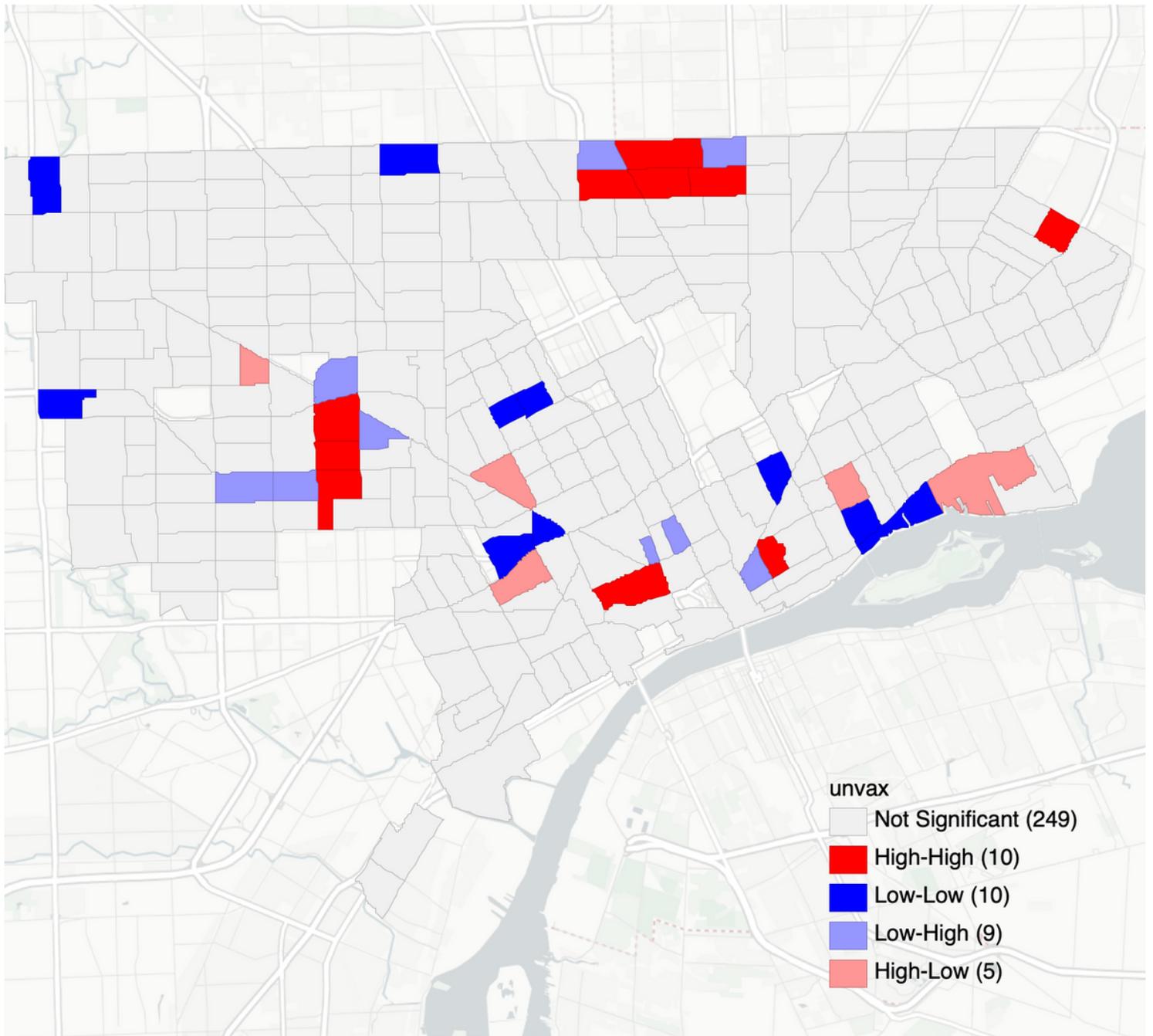


Figure 3

Hotspot clusters of unvaccinated patients.

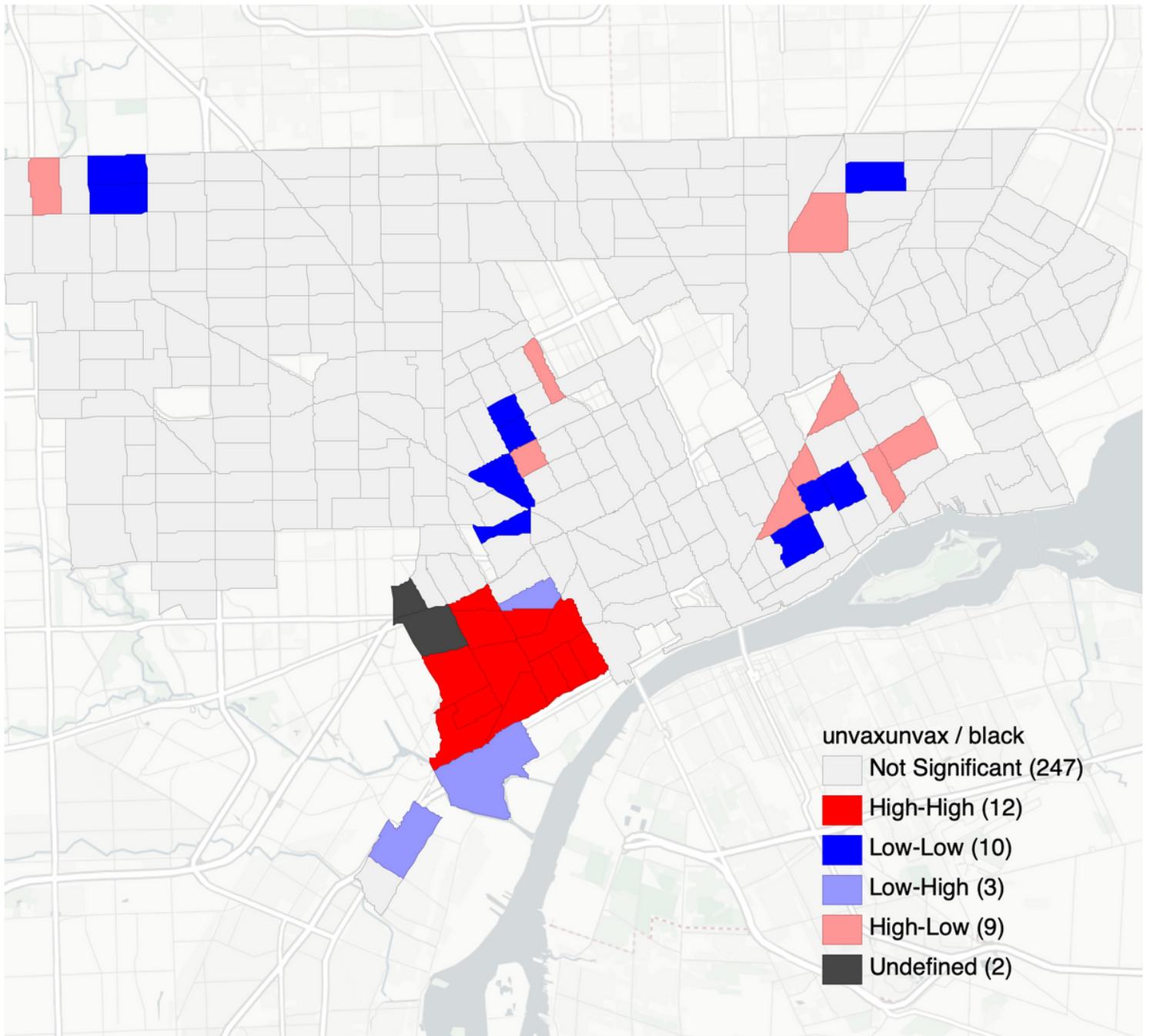


Figure 4

Hotspot clusters of Black or African American unvaccinated patients.

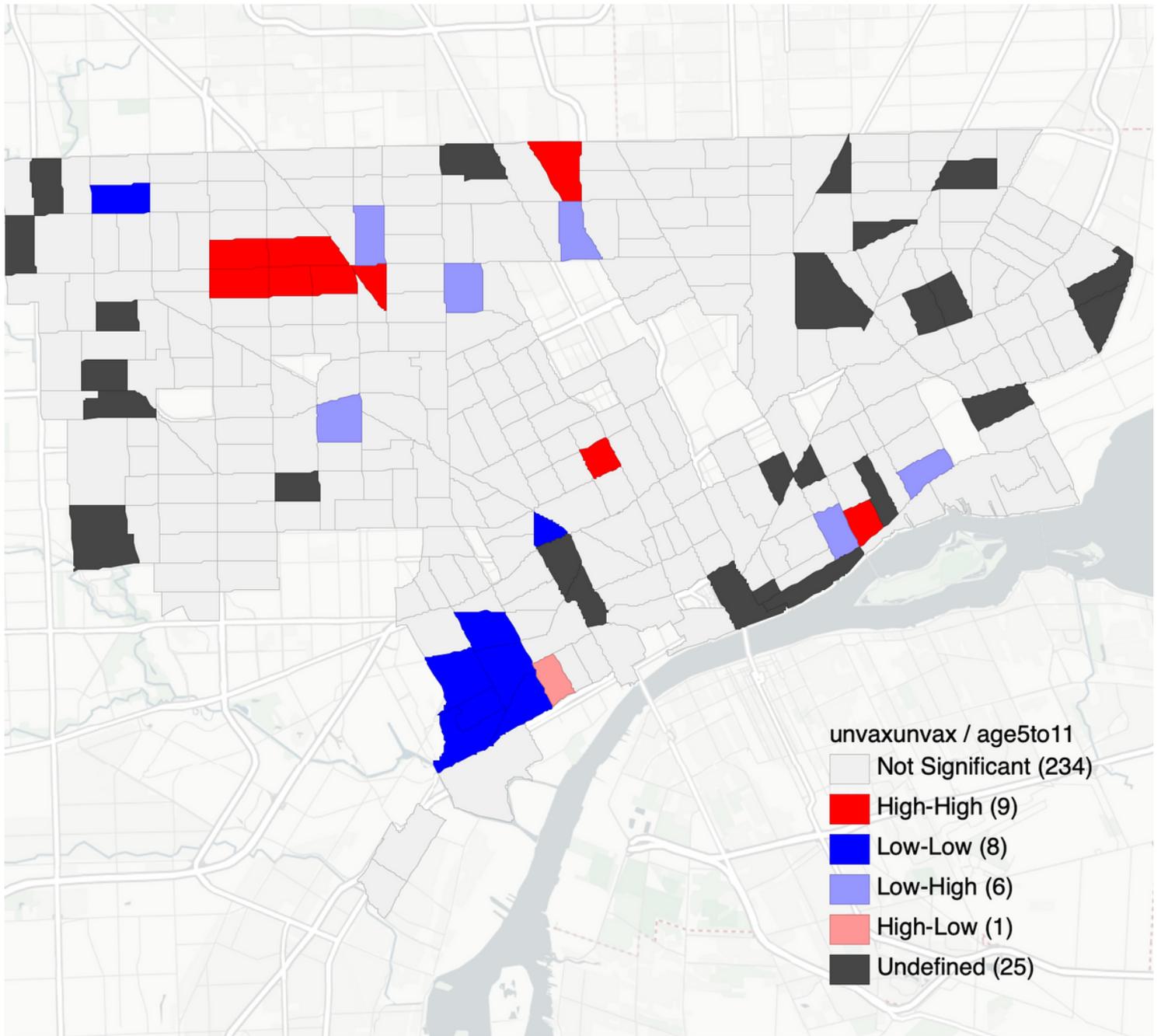


Figure 5

Hotspot clusters of age 5-11 unvaccinated patients.