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Primary Care Accessibility Effects on Health Care Utilization Among Urban Children

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Conflicts of Interest: Dr Christopher Forrest is a co-developer of the Johns Hopkins ACG Case-Mix system, which was used in this study. Johns Hopkins University owns the copyright for this software. Dr Forrest receives royalties from the distribution of the software in accordance with the University's technology transfer policy. All other authors have declared there are no conflicts of interest.

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Abstract

Objective: Evidence suggests that spatial accessibility to primary care is a contributing factor to appropriate health care utilization, with limited primary care access resulting in avoidable hospitalizations and emergency department visits which are burdensome on individuals and our health care system. Limited research, however, has examined the effects on children.

Methods: We evaluated associations of spatial accessibility to primary care on health care utilization among a sample of 16,709 children aged 0 to 3 years in Philadelphia who were primarily non-White and publicly insured. Log-Poisson models with generalized estimating equations were used to estimate incidence rate ratios (RR) and 95% confidence intervals (CI), while accounting for 3 levels of clustering (within individual, within primary care practice, within neighborhood).

Results: In age-adjusted models, the lowest level of spatial accessibility was associated with 7% fewer primary care visits (RR 0.93, 95% CI 0.91, 0.95), 15% more emergency department visits (RR 1.15, 95% CI 1.09, 1.22), and 18% more avoidable hospitalizations (RR 1.18, 95% CI 1.01, 1.37). After adjustment for individual- (race/ethnicity, sex, number of chronic conditions, insurance status) and neighborhood-level (racial composition and proportion of housing units with no vehicle), spatial accessibility was not significantly associated with rate of health care utilization.

Conclusions: Individual-level predisposing factors, such as age, race, and need, attenuate the association between accessibility to primary care and use of primary care, emergency department visits, and avoidable hospitalization. Given the possibility of modifying access to primary care unlike immutable individual factors, a focus on spatial accessibility to primary care may promote appropriate health care utilization.

Keywords: health care utilization; primary care access; spatial accessibility

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What's New

This study evaluated the effect of spatial accessibility to primary pediatric care on 3 health care utilization outcomes: primary care visits, emergency department visits, and avoidable hospitalizations in a longitudinal cohort of urban children, after controlling for clinical characteristics.

Primary care is not only the foundation of the health care system, it is the place where people get most of their medical care.[1] Individuals with good access to primary care are less likely to use the emergency department (ED)[2,3] and they are less likely to be hospitalized for conditions that can be managed in their entirety within primary care settings, so-called avoidable hospitalizations.[4] The costs of health care associated with avoidable hospitalizations and ED visits, especially for children, are a significant societal and individual burden.[5]

Avoidable hospitalizations and ED visits are not equally distributed among individuals and communities. Risk for these types of costly health service utilization is greatest among non-Whites, those of low income, and those on public insurance.[6–9] These sociodemographic inequalities in avoidable hospitalizations and ED visits may be at least partly explained by differences in spatial accessibility to primary care, or how many providers are within reasonable geographic proximity to an individual's residence.[10] Spatial accessibility to primary care, a structural element of the health system, and one determinant of primary care accessibility, could influence an individual's utilization of primary care providers, a process measure, which in turn influences the risk of ED visits and avoidable hospitalizations.[11,12] While the majority of children

receive recommended well-child checkups in the first few years, the percent varies significantly by individual socioeconomic status (SES) measures.[13,14] The use of telemedicine has increased during the COVID-19 pandemic in order to allow patients to self-quarantine while also protecting health care providers,[15] but the long-term influence of the pandemic on future use of primary care is not clear. Spatial accessibility is modifiable and measures of spatial accessibility could be used to identify neighborhoods in need of additional primary care professionals and clinics.[10]

Few studies have evaluated how spatial accessibility to pediatric care influences health care utilization. Existing studies suggest that spatial accessibility to primary care is positively associated with use of appropriate primary care[12,16] and negatively associated with inappropriate ED use or avoidable hospitalization.[11,17] However, prior studies were unable to adjust for clinical characteristics of the patients[11,12,17] and they lacked information on co-morbid conditions associated with utilization.[16] Most analyses were cross-sectional, limiting assessment of health care utilization and spatial accessibility to a single point in time.[11,12,17] Additionally, these studies were conducted in highly selected samples, restricted to children with a serious chronic condition,[16,17] with a history of prior unscheduled utilization,[16] or those with only public insurance.[12]

The Andersen Model of Health Care Utilization identifies individual-level predisposing factors as well as community-level enabling factors that determine utilization of health care services.[18] Based on this model, we addressed these limitations in prior research by conducting a study that leveraged longitudinal, detailed clinical data on patients in a large urban pediatric cohort linked with neighborhood-level characteristics, including a measure of spatial accessibility to pediatric primary care, which we have previously described.[10] Our primary aim was to determine if spatial accessibility was associated with primary care, ED visits, and avoidable hospitalization, taking into account important individual-level predisposing factors as well as other community-level enabling factors.

METHODS

The Children's Hospital of Philadelphia (CHOP) and Drexel University Institutional Review Boards approved this research.

STUDY DESIGN

We conducted a longitudinal study pooling electronic health record (EHR) data from January 2009 to December 2016. The EHR data were obtained from the CHOP patient addresses recorded for each visit were geocoded and linked to census tracts. Four groups were defined based on neighborhood (census tract-level) geographic accessibility to pediatric primary care: high, medium high, medium low, and low. Based on our hypotheses, we evaluated associations between area-level geographic accessibility and CHOP data on primary care visits, ED visits, and avoidable hospitalizations during follow-up for each group.

STUDY POPULATION AND PARTICIPANT SELECTION

CHOP is a large integrated delivery system with a primary market located in southeastern Pennsylvania, southern New Jersey and Delaware. For this study, we restricted the sample to patients with a residential address in Philadelphia County at any time during the study period. EHR data for these individuals included information from primary care, specialty care, ED, and hospital care settings. Patients aged 0 to 35 months with a physician visit from January 1, 2009, to December 31, 2016, were eligible for inclusion if they had at least 1 primary outpatient visit per year during the first 3 years of life (n = 16,709; Figure provides a flow chart of the analytic sample). We restricted the study population to children who receive primary care from CHOP at least once per year during the first 3 years of life in order to ensure that all subjects use CHOP for primary care in order to reduce the bias associated with our inability to measure visits to non-CHOP primary care providers.

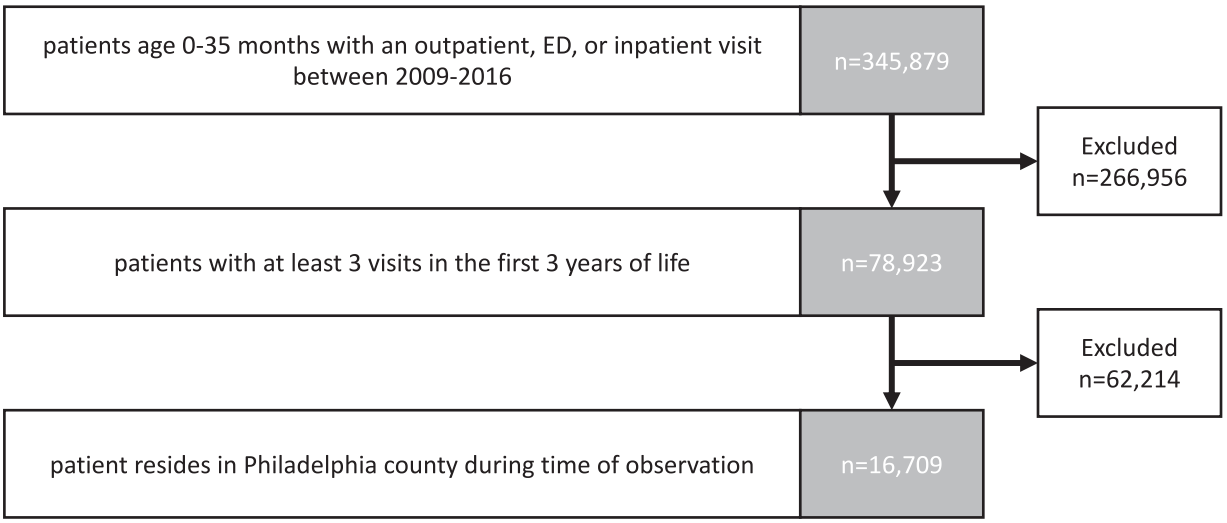

Figure. *Participants flow for analytic sample (n = 16,709).*

GEOCODING

Geocoding was done by extracting the addresses from CHOP's EHRs system (Epic Systems) and then using ArcGIS to obtain precise latitude and longitude points for a patient: 92.5% of the geocoded locations were linked to census tract boundaries and the remaining addresses were geocoded to zip code. Children geocoded to zip code were then linked to census tract using the zip codes centroid (n = 790). In some cases, children appeared to have more than one residential address as indicated by a record of at least 2 addresses recorded for at least 2 visits each during a 24-month period (eg, visit 1: address A, visit 2: address B, visit 3: address A, visit 4: address B; n = 860). We created a flag to identify possible geographic misclassification for sensitivity analyses (see below) for children geocoded to the zip code level and children with potentially more than one official primary residence (n = 1590).

SPATIAL ACCESSIBILITY TO PRIMARY CARE

We used a time varying measure of neighborhood-level accessibility to pediatric primary care. We briefly describe the creation of this measure here; additional details regarding the development and testing of this measure were published previously.[10] We obtained office addresses for all primary care providers that serve pediatric patients from SK&A Office Based Providers Database, a health care database company. Because the SK&A database did not include Federally Qualified Health Centers, we conducted a telephone survey to identify these providers. We included physicians (Doctorate of Medicine and Doctorate of Osteopathic Medicine), nurse practitioners, and physician's assistants with the specialties of internal medicine/pediatrics, family medicine, general pediatrics, or general practice. Using these data, we summed the total number of providers located within a 5-minute drive from the center of each census tract. In calculating the total number of providers, nurse practitioners and physician assistants were weighted by 0.75 to account for differences in patient loads, following the Health and Services Administrations' estimates.[19] To account for accessibility in contiguous census tracts, we also summed the total providers in all census tracts buffers sharing a border with the census tract of interest. To account for population size, we divided the total number of providers by the total pediatric population (0−17 years of age) in the census tract plus the total pediatric population in the surrounding census tracts. We evaluated geographic scales in addition to the 5-minute drive time, including 8-minute drive time and 15-minute walk time from the census tract center. The 15-minute walk time catchment areas were very small and did not consistently encompass the entire census tract, thus the measure did not accurately represent every child in the census tract. The 8-minute drive time provided estimates comparable to the 5-minute drive time. The use of the 5-minute drive time for our measure of spatial access to pediatric primary care also allowed us to directly compare our measure to a measure of spatial access to adult primary care in Philadelphia that used the same geographic scale.[20]

We classified children based on quartile of spatial accessibility score to indicate high, medium-high, medium-low, and low, and allowed their measure of spatial accessibility to change if they moved residence into a census tract with a different quartile of accessibility.

HEALTH CARE VISITS AND COVARIATES

Each participant had their own observation period, which was defined as the time in months from the initial visit to the patient's last visit during the study period. Within each patient's observation period, we counted the total number of visits to a CHOP primary care practice, ED visits, and avoidable hospitalizations. Primary care was defined as outpatient visits to 1 of 27 CHOP primary care practices in the Philadelphia metropolitan area. ED visits and hospitalizations occurred in a single facility within the main CHOP complex. Avoidable hospitalizations are admissions for health conditions that could have been prevented with adequate, accessible, and comprehensive primary care. To develop the avoidable hospitalization variable used in this study, we convened a panel of 5 pediatric clinicians, each with pediatric clinical and applied informatics expertise, to review a commonly used list of avoidable conditions.[21] To this list, the experts added constipation as an additional condition, and deleted skin grafts, which was not a health condition. Next, we translated the ICD-9-CM concepts from the list to SNOMED Clinical Terms (CT). The full list of SNOMED CT codes used for this study is available on request.

Baseline covariate data for each child were taken from the first visit in the database and included age, sex, race, and ethnicity (Hispanic or non-Hispanic). For each child, we also assessed the following characteristics longitudinally during follow-up, updating each characteristic monthly based on the medical record data from the visit closest to the start of each month: insurance status (public (includes Medicaid/SCHIP), private, or none), total number of chronic health conditions, and associated neighborhood-level variables. Individual chronic conditions were identified using the Johns Hopkins Adjusted Clinical Group software[22] and summed. EHR data for each child was linked to census tract-level data, including spatial accessibility to pediatric primary care.

We used census tract level American Community Survey 5-year estimates to assess neighborhood-level SES, proportion Hispanic, proportion non-Hispanic Black, proportion non-Hispanic Asian, and proportion of housing units with no vehicle. Neighborhood-level SES was based on 6 measures: median housing value log, percent with high school education, percent with a Bachelor's degree, percent with managerial occupation, median household income log, and percent interest/dividend income. The sum of the 6 unweighted variables was transformed into a z-score with higher values indicating better neighborhood SES or less deprivation within the census tract.[23] Given that Philadelphia has 2 children's hospitals, we also

created a ratio of the distance between child's residence and the main CHOP complex and distance between child's residence and St. Christopher's Children's Hospital as a way to control for the likelihood that a child would travel to CHOP in the case of an emergency or acute event given the relative distance between the 2 hospitals. Children's addresses were updated monthly and if patient moved they were assigned to neighborhood-level data from the new location.

ANALYSIS

Individual-level and neighborhood characteristics at baseline were compared across the 4 spatial accessibility groups using Spearman's rho to test for trends in accessibility, or chi-square test for the categorical variable that combined race and ethnicity.

We estimated the rate of primary care, ED visits, and avoidable hospitalizations over the follow-up period as total number of visits per total person-months using a generalized linear mixed model with a log-link function and Poisson error distribution, and random effects for patient, primary care practice, and census tract to address clustering.[24] Crude utilization rates per person-month were determined for each spatial accessibility group: high accessibility, moderate-high accessibility, moderate-low accessibility, low accessibility.

We built 3 multivariable regression models to estimate the rate ratios (RR) for the association between spatial accessibility and utilization adjusting for the effect of covariates at the individual- and neighborhood-levels, consistent with the Andersen Model of Health Care.[18] Data on insurance status, number of chronic conditions, neighborhood conditions, and primary care spatial accessibility were modeled as time-varying covariates. In the first model, covariates included only age and calendar year. In the second model, we added individual characteristics: sex, race/ethnicity, insurance status, and number of chronic conditions. A third model added adjustments for neighborhood-level covariates, including racial/ethnic composition and access to vehicle, which were significantly associated with the spatial accessibility measure.[10] This model also adjusted for the likelihood of visiting the main CHOP complex using the measure of the ratio of distance to CHOP to the ratio of the other children's hospital in Philadelphia because our data only included utilization information from CHOP. We did not include neighborhood SES in our final, fully adjusted model based on examination of variable inflation factors suggesting that neighborhood SES was not independent of spatial accessibility. In order to quantitatively assess a dose-response trend in the association between spatial accessibility and utilization rate, we tested the age- and year-adjusted model for a linear trend by adding the ordinal spatial accessibility variable.

Finally, we conducted several sensitivity analyses. We evaluated the potential role of bias in our findings based on the under-reporting the rate of visits for our study sample which may vary by spatial accessibility. If we have underestimated primary care visits among people differentially based on spatial access, our results bias the true association. In order to assess the direction of this error, we conducted sensitivity analyses by stratifying based on distance to closest CHOP primary care facility and CHOP hospital. Our assumption in this sensitivity analysis was that people who live closer to CHOP primary care are more likely to utilize CHOP for primary care regardless of whether they have good geographic access to primary care generally. In that case, we would expect to have fewer missing visits and thus less misclassification in the strata closest to CHOP primary care and the most misclassification in the strata farthest from CHOP primary care. Similarly for ED visits and avoidable hospitalizations, people who live closer to CHOP will be most likely to visit CHOP. In that case, we would expect to have fewer missing visits and thus less misclassification in the strata closest to CHOP and the most misclassification in the strata farthest from CHOP. Additionally, we evaluated the sensitivity of our findings to potential errors in assessment of spatial accessibility based on inaccuracy of residential address. For this analysis, we excluded children for whom address records suggested multiple residences during the period of observation or who were geocoded to zip-code level.

Regression models were checked for over-dispersion (higher variation in the data than expected) which would have inflated statistical significance. The dispersion parameters were less than one, indicating that models were under-dispersed, which probably resulted from the presence of a high proportion of zeroes in the data. The net effect of the under-dispersion rendered statistical tests more conservative.[25]

All tests were 2-sided, and P values $<.05$ were considered statistically significant. The statistical software language R (R Foundation for Statistical Computing, Vienna, Austria) was used for data analysis, and mixed models were estimated using the lme4 package for R.[26]

RESULTS

BASELINE CHARACTERISTICS

A total of 345,879 patients aged 0 to 35 months with outpatient, ED, or inpatient visits at CHOP during the study period 2009 to 2016 were eligible for inclusion. After limiting the sample to patients with at least 1 primary care visit per year during the first 3 years of life, 78,923 children were available for inclusion. We further excluded 62,214 patients who did not reside in Philadelphia County at any time during the period of observation (children who lived in Philadelphia county any part of the observation period were retained), for a final analytic sample of 16,709 patients (Figure). The characteristics of the cohort are shown by level of spatial accessibility to primary care in Table 1. During some interval within the study period over half of the patients (59%) lived in neighborhoods with low or moderately low health care accessibility. White, non-Hispanic patients, and those with private health insurance were more likely to live in

Table 1. Participant Characteristics by Primary Care Accessibility*

Variable	Total	Primary Care Accessibility*				*P*
		Low	Med-Low	Med-High	High	
N (%)	16,709	4289 (26)	5541 (33)	3477 (21)	3402 (20)	<.0001
Individual-level						
Age, mo, mean (SD)	0.79 (2.28)	0.74 (2.18)	0.74 (2.20)	0.71 (2.13)	0.79 (2.28)	.6525
Observation period, mo, mean (SD)	33.73 (2.72)	33.79 (2.65)	33.74 (2.74)	33.69(2.72)	33.68 (2.80)	.2711
Male sex, n (%)	8532 (51%)	2180 (51%)	2854 (52%)	1750 (50%)	1748 (51%)	
Race/ethnicity, n (%)						<.0001
Non-Hispanic White	3081 (18%)	232 (5%)	518 (9%)	1107 (32%)	1224 (36%)	
Non-Hispanic Black	10,830 (65%)	3486 (81%)	4248 (77%)	1646 (47%)	1450 (43%)	
Non-Hispanic Asian	603 (4%)	148 (3%)	134 (2%)	141 (4%)	180 (5%)	
Hispanic	1103 (7%)	203 (5%)	341 (6%)	296 (9%)	263 (8%)	
Other	1092 (7%)	220 (5%)	300 (5%)	287 (8%)	285 (8%)	
Health insurance status, n (%)						<.0001
Medicaid/SCHIP	12,293 (74%)	3731 (87%)	4658 (84%)	2056 (59%)	1847 (54%)	
Private/commercial	4416 (26%)	558 (13%)	883 (16%)	1421 (41%)	1555 (46%)	
Chronic conditions at last visit, n (%)						<.0001
0	13,050 (78%)	3206 (75%)	4221 (76%)	2876 (83%)	2747 (81%)	
1	3076 (18%)	931 (22%)	1112 (20%)	528 (15%)	505 (15%)	
2+	583 (3%)	172 (4%)	216 (4%)	95 (3%)	100 (3%)	
Neighborhood-level						
Percent Non-Hispanic Black, mean (SD)	59 (35)	70 (27)	74 (32)	45 (36)	37 (32)	<.0001
Percent Non-Hispanic Asian, mean (SD)	5 (8)	5 (6)	4 (9)	7 (10)	7 (8)	<.0001
Percent Hispanic, mean (SD)	6 (11)	8 (13)	5 (10)	6 (10)	6 (8)	<.0001
Percent no vehicle, mean (SD)	37 (16)	39 (13)	42 (15)	29 (17)	35 (19)	<.0001
Neighborhood SES score†, mean (SD)	−2.98 (4.93)	−5.87 (2.23)	−4.78 (3.14)	−0.673 (4.6)	1.26 (6)	<.0001

mo indicates month; SCHIP, State Children's Health Insurance Program; SD, standard deviation; and SES, socioeconomic status.

*Characteristics at baseline, unless indicated.

†Neighborhood socioeconomic status based on 6 measures (unweighted). The variables are: median housing value log, % high school graduates, % Bachelor's degree, % managerial occupation, median household income log, and % interest/dividend income. A lower number means more deprivation (lower socioeconomic status) in census tract.

neighborhoods with greater accessibility to health care. The proportion of non-Hispanic Black and proportion of housing units with no vehicle were negatively associated with spatial accessibility, while neighborhood SES was positively associated.

Spatial Accessibility and Health Care Utilization

Incidence rates and RR used to assess the independent association of spatial accessibility with the 3 outcomes are shown in Table 2. Poor spatial accessibility was associated with fewer primary care visits, more ED visits, and more avoidable hospitalizations. The overall incidence rate for primary care visits in the population was 466 per 1000 patient months, ranging from 502.7 primary care visits per 1000 patient months among children with high spatial accessibility to 437.9 per 1000 patient months among children with low spatial accessibility. For ED visits, the overall incidence rate was 70 per 1000 patient months, ranging from 55.5 ED visits per 1000 patient months to 86.8 per 1000 patient months. The rate of avoidable hospitalizations ranged from 3.6 per 1000 patient months among children with high spatial accessibility to 5.5 per 1000 patient months among children with low spatial accessibility, with an overall incidence rate of 4.6 avoidable hospitalizations per 1000 patient months.

In models adjusting for age and year, children living in neighborhoods with low spatial accessibility to pediatric primary care had 7% fewer primary care visits compared to children living in high accessibility neighborhoods (RR = 0.93, 95% confidence interval [CI]: 0.91−0.95). Compared to children living in high accessibility neighborhoods, children living in neighborhoods with low accessibility to pediatric primary care were 15% more likely to have an emergency room visit (RR = 1.15, 95% CI: 1.09−1.22) and 18% more likely to have an avoidable hospitalization (RR = 1.18, 95% CI: 1.01−1.37).

We tested the age- and year-adjusted model for linear trends in the association between spatial accessibility and utilization with spatial accessibility categories modeled as an ordinal variable. The results provided further support for a dose-response relationship between spatial accessibility and health care utilization (primary care visits: RR = 1.06, 95% CI: 1.04−1.12, $P < .001$; ED visits: RR = 0.88, 95% CI: 0.84−0.91, $P < .001$; avoidable hospitalizations: RR = 0.90, 95%CI: 0.81−1.01, $P = .062$).

The observed linear association between spatial accessibility and health care visits was substantially attenuated after the addition of individual-level characteristics, including number of chronic conditions and insurance status (Table 2, model 2). After further adjustment for neighborhood-level characteristics, including neighborhood racial composition, access to vehicle, and ratio of distance to CHOP versus other children's hospital, the association of spatial accessibility with utilization was no longer statistically significant.

In sensitivity analyses stratified by distance to nearest CHOP primary care site, the effect estimate for the

Table 2. Incidence Rates and Rate Ratios for Health Care Visits by Spatial Accessibility

	High Access	Moderate-High Access	Moderate-Low Access	Low Access
Primary care visits				
Number of events	58,517	59,283	86,823	65,815
Incidence rate (per 1000 patient months)	502.7	491.4	450.1	437.9
Model 1 (95% CI)	1.0 (reference)	0.98 (0.96–1.00)	0.95 (0.94–0.97)	0.93 (0.91–0.95)
Model 2 (95% CI)	1.0 (reference)	0.99 (0.97–1.01)	0.99 (0.97–1.01)	0.97 (0.95–0.99)
Model 3 (95% CI)	1.0 (reference)	0.99 (0.98–1.01)	1.00 (0.98–1.02)	0.98 (0.96–1.00)
Emergency department visits				
N	6458	5669	15,232	13,049
Incidence rate (per 1000 patient months)	55.5	47.0	79.0	86.8
Model 1 (95% CI)	1.0 (reference)	0.96 (0.90–1.02)	1.12 (1.06–1.18)	1.15 (1.09–1.22)
Model 2 (95% CI)	1.0 (reference)	0.91 (0.86–0.97)	0.99 (0.94–1.05)	1.01 (0.96–1.07)
Model 3 (95% CI)	1.0 (reference)	0.96 (0.91–1.02)	0.99 (0.94–1.04)	1.02 (0.97–1.08)
Avoidable hospitalizations				
N	417	447	947	834
Incidence rate (per 1000 patient months)	3.6	3.7	4.9	5.5
Model 1 (95% CI)	1.0 (reference)	1.14 (0.96–1.34)	1.10 (0.95–1.27)	1.18 (1.01–1.37)
Model 2 (95% CI)	1.0 (reference)	1.08 (0.92–1.27)	0.96 (0.83–1.10)	0.99 (0.85–1.14)
Model 3 (95% CI)	1.0 (reference)	1.17 (0.99–1.38)	0.98 (0.84–1.14)	1.04 (0.89–1.21)

CI indicates confidence interval.

Multivariable model 1 was adjusted for age and year.

Multivariable model 2 was adjusted for age, race/ethnicity, sex, number of chronic conditions, insurance status, and year. Multivariable model 3 was adjusted for age, race/ethnicity, sex, number of chronic conditions, insurance status, year, proportion Hispanic, proportion non-Hispanic Black, proportion non-Hispanic Asian, proportion of housing units with no vehicle, and ratio of distance to CHOP versus other children's hospital.

association between low spatial access and primary care visits did not differ comparing the strata nearest to CHOP primary care and the strata furthest from CHOP primary care (0.94 and 0.93, respectively) and both were similar to the overall estimate (0.93). This suggests minimal bias associated with measuring CHOP primary care visits only. The effect estimate for the association between low spatial access and ED visits was slightly larger among children living closest to CHOP (1.50) compared to children living furthest from CHOP (1.32). Both estimates were larger than the overall estimate (1.15). The effect estimate for the association between low spatial access and avoidable hospitalization was slightly larger among children living furthest from CHOP (2.24) compared to children living closest to CHOP (1.22). The estimate for children living closest to CHOP was similar to the overall estimate (1.18). Our sensitivity analyses stratified by distance to closest CHOP primary care provider did not differ between the closest and furthest strata suggesting limited bias associated with undercounting primary care visits to non-CHOP providers. However, results of sensitivity analyses stratified by distance to CHOP suggest we've underestimated the association between spatial access and ED use and avoidable hospitalization as a result of missing non-CHOP utilization (Appendix).

In the selected cohort in which patients with possible misclassification of neighborhood location were excluded, the RR for spatial accessibility were slightly larger (Appendix).

Discussion

Children who live in urban neighborhoods with low spatial accessibility to primary care had fewer primary care visits, more ED visits, and more avoidable hospitalizations within the health system we measured. The magnitude of the association between spatial accessibility and utilization was small and individual sociodemographic and clinical characteristics explained most of the increased risk. Our findings are consistent with the Andersen Model of Health Care Utilization indicating that while community-level enabling factors such as accessibility to primary care contribute to utilization of health care services, individual-level predisposing factors, such as need (eg, number of chronic conditions and insurance status), are the most important drivers.[18] Nearly all children have financial access to health care through state Children's Health Insurance Programs and the Affordable Care Act, private insurance or Medicaid. Given the mutability of primary care access locations, these data suggest that increasing spatial accessibility for an urban, insured population may promote appropriate health care utilization among children.

Unlike prior research that reported lower spatial accessibility to pediatric primary care was related to a decrease in scheduled asthma care,[16] an increase in ED visits for asthma,[17] and lower chances of a child being up to date on vaccines,[12] we did not find a significant association after controlling for individual-level and neighborhood-level predisposing and enabling factors. Mathison and colleagues[11] observed a linear exposure-response relationship between odds of a nonurgent pediatric ED visits and neighborhood primary care provider density: for every 1 unit increase in density, the odds of a nonurgent ED visit decreased by 9%. In the current analysis, we were able to adjust for co-morbid conditions associated with utilization, an important predisposing factor not included in most of the prior research.

This study has several limitations. We restricted the study population to children who receive primary care from CHOP at least once per year during the first 3 years of life. If our sample selection criteria resulted in a greater likelihood of including children with better accessibility and greater likelihood of using primary care, then results may be an under-estimation effect of accessibility and avoidable hospitalization or ED use. Additionally, we have information about utilization at CHOP only. Ideally, we would have access to information regarding all primary care and hospitalization/ED use among the study sample. While CHOP is the largest pediatric care provider serving Philadelphia, we are missing visits from all non-CHOP providers. Limiting the sample to children who use CHOP for primary care reduces the error in outcome ascertainment associated with use of non-CHOP primary care providers. However, if measurement error in the outcome varied by spatial accessibility, estimates of the association would be biased. In our sensitivity analyses stratified by distance to CHOP, we observed that estimates of the association between spatial accessibility and utilization were consistently lower in the strata closest to CHOP compared to the strata furthest from CHOP. These results suggest that as a result of missing non-CHOP utilization, we have underestimated the association between spatial access and ED use and avoidable hospitalization. However, our sensitivity analyses stratified by distance to the closest CHOP primary care provider did not differ between the closest and furthest strata suggesting limited bias associated with undercounting primary care visits to non-CHOP providers. Misclassification of spatial accessibility based on problems with address data would bias results toward the null. This is consistent with our sensitivity analyses excluding those with greatest likelihood of misclassification in which results were slightly stronger. We only had data on visits to CHOP and thus we may have missed some outcomes of interest. However, adjusting for the relative distance to CHOP compared to the other children's hospital did not change the results. We did not include an evaluation of urgent care visits in our study. Understanding drivers for utilization patterns of alternative primary care options (eg, retail clinics, urgent care, and telemedicine) is an important topic for future research, especially as these options become more common.[27] This analysis is limited to residents of Philadelphia, Pennsylvania, and further work is needed in other geographic areas. Finally, while telemedicine is essential to protect patients and providers during a public health emergency (eg, current COVID-19 pandemic), the future of virtual health care is unknown. Dramatic increased use of telemedicine for the primary care of pediatric patients would potentially diminish the relevance of spatial accessibility for understanding health care utilization.

This study has many strengths. We followed an urban cohort of children up to 8 years. We had detailed, multilevel and multidimensional data from a large pediatric hospital system involving all clinical settings on each child in the cohort. We linked EHR data to neighborhood-level characteristics longitudinally, including spatial accessibility to pediatric primary care. The definition of avoidable hospitalization was adapted from an existing definition to improve comparability to prior research.[21] Finally, this is the first study to our knowledge that investigates spatial accessibility within an urban setting to pediatric primary care's relationship to multiple health utilization outcomes.

CONCLUSIONS

Spatial accessibility to pediatric primary care within an urban context plays a role in patterns in health care utilization including ED visits, primary care visits, and avoidable hospitalizations. These results can guide efforts to address unnecessary ED visits and hospitalizations. Addressing neighborhood disparities in accessibility to primary care would likely also reduce disparities in health care utilization among children. This project previously reported racial disparities in neighborhood-level spatial accessibility to pediatric primary care.[10] Addressing these disparities could have important effects on health care utilization patterns for the whole of the city. This research also confirms the role of primary care services in controlling health care costs. Further research is needed to assess the role of primary care accessibility in ensuring continuity of care and receipt of appropriate primary care.

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SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at https://doi.org/10.1016/j.acap.2020.05.014.

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