Access to cardiac surgery centers for cardiac and non-cardiac hospitalizations in adolescents and adults with congenital heart defects- a descriptive case series study

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Abstract

Background—Individuals with congenital heart defects (CHDs) are recommended to receive all inpatient cardiac and noncardiac care at facilities that can offer specialized care. We describe geographic accessibility to such centers in New York State and determine several factors associated with receiving care there.

Methods—We used inpatient hospitalization data from the Statewide Planning and Research Cooperative System (SPARCS) in New York State 2008–2013. In the absence of specific adult CHD care center designations during our study period, we identified pediatric/adult and adult-only cardiac surgery centers through the Cardiac Surgery Reporting System to estimate age-based specialized care. We calculated one-way drive and public transit time (in minutes) from residential address to centers using \texttt{gmapsdistance} package and the Google Maps Distance Application Programming Interface (API). We calculated prevalence ratios using modified Poisson regression...
with model-based standard errors, fit with generalized estimating equations clustered at the
hospital level and subclustered at the individual level.

**Results**—Individuals with CHDs were more likely to seek care at pediatric/adult or adult-only
cardiac surgery centers if they had severe CHDs, private health insurance, higher severity of illness
at encounter, a surgical procedure, cardiac encounter, and shorter drive time. These findings can be
used to increase care receipt (especially for noncardiac care) at pediatric/adult or adult-only
cardiac surgery centers, identify areas with limited access, and reduce disparities in access to
specialized care among this high-risk population.

**Background**

A decline in mortality from congenital heart defects (CHDs), attributed to advancement in
diagnostic measures and medical and surgical therapies,\(^1\)–\(^3\) has resulted in a growing
population of individuals with CHDs who require lifelong care for cardiac and noncardiac
comorbidities.\(^4\)–\(^7\) In recognition of the need for lifelong specialized care, the Bethesda
guidelines, published in 2002, began to outline the importance of specialized care centers for
individuals with CHDs.\(^8\) In 2008, an American Heart Association (AHA) Scientific
Statement recommended that individuals with CHDs start a formal transition process from
pediatric to adult healthcare by age 12 with a successful transfer to adult care achieved by 18
to 21 years.\(^9\) Recent American College of Cardiology (ACC)/AHA consensus guidelines
recommend that physicians caring for individuals with CHDs should support access to care
by ensuring smooth transitions for adolescents and young adults from pediatric to adult
providers and should promote awareness of the need for lifelong specialized care.\(^7\) These
guidelines specifically establish that preoperative evaluation, risk assessment, and surgery
for adult CHD patients should occur in regional cardiac care centers because of access to
congenital cardiology care, experienced surgeons, and cardiac anesthesiologists. Although
no formal accreditation for CHD care existed at the time of the study, New York State (NYS)
licenses pediatric/adult cardiac surgery centers as those facilities that offer pediatric cardiac
surgery to children under 18 years in addition to adults and adult-only cardiac surgery
centers as facilities licensed to offer cardiac surgery only to adults ages 18 years and older.\(^10\)

The period of adolescence and young adulthood is a critical period in CHD care. Adolescents and young adults, in the transitional period between pediatric and adult care, have been found to be at increased risk of experiencing lapses in routine cardiac care. Literature suggests that a large proportion of individuals with CHDs do not transition successfully to adult care and less than 30% of adults with CHDs are seen by appropriate specialty cardiac care providers.\(^11\)–\(^13\) Lapses in care have been linked to a number of adverse outcomes, including an increase in concomitant morbidities, a reduction in reported quality of life, and greater mortality.\(^14\) Previous studies have suggested that proximity to care may be barrier to care, potentially resulting in such lapses.\(^15\),\(^16\)

The impact of patient residential location, a key factor determining adequate access to
care\(^17\)–\(^18\) on healthcare utilization,\(^19\)–\(^22\) has not been investigated extensively among people
with CHDs. In a previous pilot study, Sommerhalter et al.\(^23\) found that the highest predicted
one-way travel times were among those living in rural, high-poverty areas. In addition to
geographic location, individual characteristics such as socioeconomic status, age, and CHD severity; encounter level characteristics such as health insurance, type of illness and its severity; and center characteristics such as teaching status and accessibility through public transport, may influence healthcare utilization among individuals with CHDs. However, no studies have examined these factors in relation to receipt of inpatient care at a pediatric/adult or an adult-only cardiac surgery center. Recent improvements in spatial data processing capabilities and drive distance analysis now allow for vehicular travel time to be modeled more easily using a geographic information system (GIS).

Objectives

We sought to determine whether adolescents and young adults with CHDs were receiving cardiac and non-cardiac inpatient care at cardiac surgery centers in NYS. Cardiac surgery centers were defined as pediatric/adult cardiac surgery centers for those under 18 years of age and pediatric/adult or adult-only cardiac surgery centers for those 18 years or older. We chose cardiac surgery centers to serve as proxies for centers offering highly specialized CHD care. We further examined associations between travel time as a potential barrier as well as other individual, encounter, and hospital level factors with receipt of inpatient care at cardiac surgery centers.

Methods

Data was collected on hospitalizations from SPARCS, on cardiac surgery programs from the Cardiac Surgery in New York State Reports, and on census tract level sociodemographics from the 2010 Census, the 2008–2012 American Community Survey (ACS), and the 2010 Rural Urban Commuting Survey. Because of the sensitive nature of the data collected for this study, requests to access the hospitalization dataset may be sent to SPARCS, NYS Department of Health (sparcs.requests@health.ny.gov) from qualified researchers trained in human subject confidentiality protocols. All other data are publicly available from the referenced sources above.

Study design and participants

This retrospective observational study was approved by the NYS Department of Health Institutional Review Board. We identified cases using hospital inpatient encounter data between January 1, 2008 and December 31, 2013 from SPARCS, an all-payer reporting system in NYS. An adolescent or young adult (defined as those between 11 and 30 years of age as of January 1st, 2013) was considered to have a CHD if he or she had documentation of one or more of the following International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) codes as a primary or secondary diagnosis code in SPARCS: 648.5X, V13.65, 745.XX-747. XX, excluding 746.86 (congenital heart block), 747.32 (pulmonary arteriovenous malformation), 747.5 (absence or hypoplasia of umbilical artery), 747.6 (other anomalies of peripheral vascular system), and 747.8 (other unspecified anomalies of the circulatory system) because these codes may not be specific to CHDs. A full list of eligible CHD-related diagnosis codes is included in Appendix Table A5.
Facilities

In NYS, cardiac surgery centers are designated based on criteria specified in NYS Public Health Laws Article 10 CRR-NY 709.14 and Article 10 CRR-NY 405.29,32, 33 We identified cardiac surgery centers from 2006–2013 reports on cardiac surgery developed collaboratively by the NYS Department of Health Cardiac Services Program and the NYS Cardiac Advisory Board using data from the Cardiac Surgery Reporting System.34 Pediatric cardiac surgery centers were licensed to offer pediatric cardiac surgery to children under 18 years. All the pediatric cardiac surgery centers were also licensed to offer adult cardiac surgery (hereafter referred to as “pediatric/adult cardiac surgery centers”). Adult cardiac surgery centers were facilities licensed to offer cardiac surgery only to adults ages 18 years and older (hereafter referred to as “adult-only cardiac surgery centers”). Because some hospitals were not licensed to conduct cardiac surgery for the entire study period, we identified the specific months/years that each cardiac surgery center was licensed to perform pediatric and/or adult cardiac surgery.

Outcome

For each clinical encounter, we calculated whether the visit occurred at a cardiac surgery center based on patient’s age at the time of the visit. If the patient was < 18, we deemed the visit to have occurred at a cardiac surgery center if the center was licensed to perform pediatric cardiac surgery at the time of admission for the encounter. Similarly, if the patient was 18 or over, the visit was deemed to have occurred at a cardiac surgery center if it was licensed to perform adult cardiac surgery at the time of admission.

Covariates

We conceptualized that covariates at individual, encounter, and facility level would act concomitantly to influence whether an individual receives care at a cardiac surgery center (Figure 1). Within each hospitalization record, we identified the admission date, age of patient, and residential address at admission.

**Individual level variables**—Individual level variables included sex, race/ethnicity, CHD severity, census tract poverty, and rurality. We categorized cases as severe (having required surgical or catheter intervention in the first year of life) or nonsevere using ICD-9-CM diagnosis codes aggregated across hospital inpatient encounter records for each case. If a case had at least one severe CHD ICD-9-CM diagnosis code, that case was classified as having severe CHD. Residential addresses were assigned to one of eight health service areas (HSAs), or geographical subdivisions of NYS based on address county. We then collapsed the eight HSAs into two mutually exclusive categories (New York City [NYC] and non-NYC). Census tracts corresponding to the geocoded residential addresses were identified using 2010 US Census boundary data. We used the 2010 Census and the 2008–2012 ACS to determine census tract rurality and poverty, respectively.29, 30 In particular, we matched each census tract to its corresponding 2010 Rural-Urban Commuting Area (RUCA) code, which classifies a census tract based on its population density, urbanization, and daily commuting. Each census tract was then designated as either rural or urban. The 2008–2012 ACS was used to calculate the percent of the population living at or under the federal poverty level.
(FPL) for each census tract. Based on the Census Bureau definition, we dichotomized census tracts as low poverty areas (< 20% of the population living at or under the FPL) and high poverty areas (≥ 20% of the population at or under the FPL).

**Encounter level variables**—Encounter level variables included age at encounter, insurance type, admission type, encounter type, and severity of illness. All Patient Refined Diagnosis Related Group (APR DRG) codes are hospitalization classifications incorporating the primary reason for hospitalization, patient severity of illness (SOI: the extent of organ system derangement or physiologic decompensation for a patient), and type of encounter (surgical or nonsurgical). We categorized the primary reason for hospitalization into mutually exclusive cardiac (includes vascular) and non-cardiac categories; and categorized APR DRG SOI as minor, moderate, major, and extreme severity. Other hospitalization encounter level variables of interest included individual’s age at encounter; insurance type (private/commercial, Medicaid, Medicare, self-pay/uninsured, other, or unknown based on primary payment source); and admission type (emergency: patient requires immediate medical intervention because of a severe or life-threatening condition, urgent: patient requires immediate attention for the care and treatment of a physical or mental disorder, elective: patient condition permits adequate time to schedule the admission, other, or unknown).

Hospital level variables included proximity and teaching status. For each hospitalization, we calculated proximity from residential address to closest cardiac surgery center using the list of centers approved to conduct surgery on the corresponding admission date. We determined teaching status for each hospital using the Centers for Medicare and Medicaid Services Open Payments list of teaching hospitals for 2013.35

**GIS Analysis**

We extracted residential addresses for eligible cases from SPARCS hospital inpatient records, excluding post office boxes, addresses listed as undomiciled, and those that matched hospital addresses. Similarly, we extracted the names and addresses of the hospitals where CHD cases received inpatient care for any reason over the study period. For each hospitalization, the identified hospital was classified as a pediatric/adult cardiac surgery center, an adult-only cardiac surgery center, or not a cardiac surgery center (hereafter referred to as a “non-cardiac center”) at the time of the hospitalization. We geocoded all eligible residential addresses and hospitals using ArcMap and New York State Street and Address Maintenance Program, a statewide address point database. Street level geocoding was successfully performed for 4,779 (92.4%) residential addresses then zip-code centroid geocoding was performed for the remaining 390 addresses. We successfully geocoded all hospitals at the street level.

We estimated one-way drive time (in minutes) from patient residential address at hospital inpatient encounter to 1) the hospital where the patient received care and 2) the closest cardiac surgery center. One-way drive times and one-way public transit times from patient residential address to the hospitals were estimated using the *gmapsdistance* package in R and the Google Maps Distance Application Programming Interface (API).36 Because the Google
API retrieves times based on the date and time of the query, we restricted queries to morning and early afternoon to reflect travel times expected for daytime visits to hospitals. Transit calculations were limited to areas with public transit data available in the Google API. If an individual received care at different hospitals on different dates or moved during the study period, each unique address-hospital pair was retained in the database.

To determine whether there were disparities in geographic accessibility to cardiac surgery centers in NYS, we estimated whether travel time was associated with receipt of care at a cardiac surgery center (yes/no). Due to road network structures and traffic patterns, a center closest by straight-line distance on the map may not be the closest center when driving. We therefore used a two-step process whereby we first identified the three closest cardiac surgery centers by a straight-line distance for each patient address. We then used the gmapsdistance package and the Google Maps Distance Matrix API to calculate one-way drive time and one-way public transit time from each residential address to each of the three cardiac surgery centers nearest to that address. Then, we selected the center with the shortest drive time as the closest cardiac surgery center and used this drive time in the statistical analyses.

**Statistical analysis**

We characterized the inpatient care received by adolescent and young adults with CHDs and determined the percent of inpatient care received at cardiac surgery centers for cardiac encounters, non-cardiac encounters, as well as for surgical cardiac encounters. For cardiac and non-cardiac hospitalizations, we summarized one-way drive time and one-way public transit time to hospitals where care was received and to the closest cardiac surgery center, both overall and stratified by region-rurality and census tract poverty. Since data on drive times showed significant skew, we used median drive times as a measure of central tendency. We chose to report results including outliers to provide a more complete picture of actual travel experiences in the study population. Chi-square tests, Wilcoxon Rank-Sum tests, Kruskal Wallis tests, and Dwass, Steel, Critchlow-Fligner multiple comparison tests were used to test for significant differences across strata. Since all missing values represented less than 20% of a given variable, no imputation was made for missing data.

**Multivariate analysis**

To understand whether selected individual, encounter, and hospital level factors were associated with receiving care at cardiac surgery centers for all hospitalizations, we calculated prevalence ratios at the encounter level using modified Poisson regression with model-based standard errors, fit with generalized estimating equations clustered at the hospital level and sub-clustered at the individual level. We used a nested model approach to determine separate contributions and mediation effects of individual (including residential address level), encounter, and hospital level variables. We fit three models: (1) a model containing individual level factors, (2) a model containing individual and encounter level factors, and (3) a model containing individual, encounter level factors, hospital teaching status, and one-way drive time to the closest cardiac surgery center. In sensitivity analyses, we restricted to elective/urgent admissions, excluding emergency admissions, because patients may not have a choice but to travel to the closest hospital for emergency care and
because emergencies may occur away from home where another cardiac surgery center is closer. We also conducted a sensitivity analysis excluding adult only centers in consideration of these not necessarily being equipped to offer specialized CHD-specific care. Finally, we assessed distance to care among transfer admissions. Continuous variables, including distance to cardiac surgery center, were log-transformed when their distribution was skewed. Since the associations between race/ethnicity, poverty, and insurance status can be complex we checked for effect modification by these variables using interaction terms in the model. All GIS and statistical analyses were performed using ArcGIS 10.3, R 3.3.2, and SAS 9.3 (SAS Institute Inc, Cary, NC).

Results

Facilities

There were 42 hospitals in NYS that met cardiac surgery center criteria during the study period (Figure 2). Of the 42 cardiac surgery centers, 11 (26.2%) were certified as pediatric/adult cardiac surgery centers, the rest are adult-only cardiac surgery centers; 36 (85.7%) were listed as teaching hospitals. All but four cardiac surgery centers (one pediatric/adult and three adult-only) were licensed for the duration of the surveillance period; one center stopped performing pediatric cardiac surgery in 2008; two others stopped performing adult cardiac surgeries in 2010 and 2013; and one center began performing adult cardiac surgeries in 2011. Individuals with CHDs sought inpatient care at 154 noncardiac centers during the study period, of which 61 (39.7%) were listed as teaching hospitals.

Characteristics of the study population

There were 4,962 individuals with CHDs in the 11 to 30-year age group during the study period. Of these, 36 individuals were excluded because they did not have a geocodable residential address or were listed as homeless. The final sample size for analysis was therefore 4,926 cases with CHD (Table I). About 53% of cases were female, 13% of cases had severe CHDs, and about half of all cases were non-Hispanic white. Cases had 5,169 unique eligible residential addresses (data not presented). Approximately 45% of these addresses were in NYC, 95.8% were in urban census tracts, and 35.1% were in high poverty census tracts.

Table II contains information on the 6,939 inpatient hospitalizations over the study period for eligible CHD cases (mean number of hospitalizations per individual: 1.4; range 1–39). Overall 70.5% of encounters among CHD cases occurred at a cardiac surgery center. Of all inpatient hospitalizations, 3,136 (45.2%) were for cardiac reasons. Among cardiac encounters, 86.8% occurred at a cardiac surgery center while only 57.2% of noncardiac encounters were at a cardiac surgery center. Overall, private/commercial insurance was the primary insurance type for most hospitalizations (69.0%). Over half of the hospitalizations were emergency admissions, and 59.5% were nonsurgical encounters. About 45% of all hospitalizations had a moderate SOI and 31% had a major SOI. A greater proportion of cardiac hospitalizations were classified as elective (53.5%) and surgical (62.2%) compared to noncardiac hospitalizations (23.3% and 22.7%, respectively; \(P < .0001\)).
Cardiac hospitalizations

A majority of cardiac encounters (95.7%) occurred at teaching hospitals (data not presented). Of all cardiac encounters, 86.8% occurred at a cardiac surgery center; 29.7% were at the closest cardiac surgery center, while 57.1% were at a cardiac surgery center that was not the closest (Appendix Table A1). Overall, only 10.6% of cardiac encounters occurred at centers not licensed to offer cardiac surgery; 6.9% occurred at a noncardiac center closer than the nearest cardiac surgery center and 3.7% occurred at a noncardiac center farther than the closest cardiac surgery center. Further, 97.4% of cardiac surgical hospitalizations occurred at a cardiac surgery center (data not presented). However, 24.2% of emergency cardiac encounters occurred at a noncardiac center, whereas only 2.5% of nonemergency cardiac encounters occurred at a noncardiac center (data not shown).

Table III shows the results of unadjusted and multivariate nested models predicting care receipt at a cardiac surgery center for all cardiac hospitalizations. In model 1 which includes only individual level characteristics, patients with severe CHD (aPR = 1.07), compared to nonsevere CHD, were slightly more likely to receive care at cardiac surgery centers. Non-Hispanic blacks (aPR = 0.94), compared to non-Hispanic whites, and those in non-NYC urban and rural areas (aPR = 0.95 and 0.90, respectively), compared to those residing in NYC, were slightly less likely to receive care at a cardiac surgery center.

In model 2 with individual and encounter level factors, receipt of care at a cardiac surgery center was associated with severe CHD, living in NYC, younger age at encounter, private/commercial insurance, urgent and elective encounters, surgical encounters, and major SOI. In model 3 with individual, encounter, and hospital level factors, CHD severity and non-NYC rural residence were the only individual level characteristics associated with receiving care at a cardiac surgery center. Associations for encounter level characteristics, except age at encounter, were similar to model 2. Additionally, for every 1-minute increase in one-way drive time from residential address to closest cardiac surgery center, the individual was 8% less likely to receive care at a cardiac surgery center (aPR=0.92). Individuals were also three times more likely to receive care at a cardiac surgery center if it was a teaching hospital (aPR=3.1). There were no statistically significant interactions between race/ethnicity, poverty, and insurance status. The median one-way drive time from residential address to the hospital where inpatient care was received was 32.2 minutes (range: 0.5–331.8) for cardiac hospitalizations (Table V). Median one-way drive time from residential address to the hospital was significantly shorter in NYC and urban, non-NYC areas compared to rural areas, and for high poverty areas compared to low poverty areas.

Public transit was available from the residential address to the hospital where care was received for 78.3% of the cardiac hospitalizations. Median one-way transit time was 62.0 minutes (range: 0.3–724.3) for cardiac hospitalizations. Public transit availability varied significantly by region-rurality and area poverty for both types of hospitalizations.

For cardiac hospitalizations, median one-way drive time from residential address to the closest cardiac surgery center was 20.3 minutes overall (range: 0.5–199.7) (Table V). Median one-way drive time was significantly shorter in NYC and urban, non-NYC areas compared to rural areas, and in high poverty census tracts compared to low poverty census areas.

Am Heart J. Author manuscript; available in PMC 2022 June 01.
tracts. Public transit was available from residential address to a cardiac surgery center for 79.4% of the cardiac hospitalizations. Median one-way transit time among these hospitalizations was 42.8 minutes (range: 0.3–443.2). In rural areas, public transit was only available for 7.2% of cardiac hospitalizations.

Noncardiac hospitalizations

Only 56.9% of noncardiac encounters occurred at a cardiac surgery center, whereas 36.1% occurred at a center not licensed for cardiac surgery and 13.0% occurred at a noncardiac center farther than the closest cardiac surgery center. For noncardiac encounters, receipt of care at a cardiac surgery center did not differ for emergencies (36.8%) and nonemergencies (35.2%). Teaching hospitals were the site of 81.9% of encounters.

Table IV shows the results of the unadjusted and multivariate nested models predicting care receipt at a cardiac surgery center for all hospitalizations for noncardiac encounters. Overall, associations were similar, but slightly stronger for noncardiac encounters compared to cardiac encounters. In model 1, including only individual level characteristics, patients with severe CHD (aPR=1.10), compared to nonsevere CHD, were more likely to receive care at cardiac surgery centers. Those in high poverty areas were 8% less likely to receive care at a cardiac surgery center. In addition, those in non-NYC urban areas were 12% less likely and those in rural areas were 40% less likely compared to those residing in NYC, to receive care at a cardiac surgery center. In the sensitivity analysis restricted to urgent and elective cardiac encounters, excluding 3,548 emergency admissions, estimates were slightly less precise and CHD severity, insurance type, and drive time to the closest cardiac surgery center were no longer associated with receipt of care at a cardiac surgery center.

Model 2 results for noncardiac encounters were similar to that for cardiac encounters, with additional associations between receipt of care with other insurance and stronger associations with SOI. In model 3, non-Hispanic blacks and those residing in high poverty areas were significantly less likely to receive care at cardiac surgery centers. Conversely, those in non-NYC urban and rural areas were more likely to receive care at cardiac surgery centers after adjusting for hospital level variables. The associations for the other individual and encounter level variables were similar in direction but somewhat attenuated. Finally, for every 1-minute increase in drive time to a cardiac surgery center, individuals seeking care for non-cardiac conditions were 29% less likely to receive care at a cardiac surgery center. If the center was also a teaching hospital, individuals were six times more likely to receive care at that cardiac surgery center. Results were similar when restricting to urgent and elective noncardiac encounters, though census tract poverty and rurality were no longer associated with receipt of care at cardiac surgery centers. There were no statistically significant interactions between race/ethnicity, poverty, and insurance status.

The median one-way drive time from residential address to the center where inpatient care was received was 20.7 minutes (range: 0.1–384.6) for noncardiac hospitalizations (Table V). Public transit was available for 75.3% of noncardiac hospitalizations with a median transit time of 46.0 minutes (range: 1.8–749.4). In rural areas, public transit was only available for 5.3% of noncardiac hospitalizations.
Additional analysis

We conducted a sensitivity analysis with a more conservative definition of cardiac care, including only those centers licensed in both pediatric and adult cardiac surgery as cardiac surgery centers for both adolescents and adults (Appendix Tables A2 & A3). There was a maximum of 11 pediatric/adult cardiac surgical centers in our study period, all of which were large urban teaching hospitals. As expected, the effects of distance, age, and rurality status were accentuated. However, non-Hispanic Blacks and Hispanics were more likely to seek care at cardiac surgery centers for cardiac encounters compared to the larger analysis.

Additionally, we looked at cases of transfers to another hospital (Appendix Table A4). A large proportion of such cases were transferred to pediatric/adult cardiac surgical centers (68.3% of cardiac and 56.6% of noncardiac transfers). The drive times for transfers made to pediatric cardiac surgery centers were significantly higher than for transfers to hospitals without the pediatric cardiac surgery center designation.

Discussion

In a comprehensive descriptive case-series analysis of inpatient encounters in adolescents and young adults with CHDs in NYS from 2008 to 2013, we found that a large percentage of inpatient cardiac care was received at cardiac surgery centers, median drive time was under 30 minutes to the nearest cardiac surgery center, and public transit was available for the vast majority of hospitalizations. Individuals with CHDs in NYS were significantly less likely to seek care at cardiac surgery centers for nonsurgical procedures and noncardiac encounters during the study period. We further found that individuals were less likely to visit a cardiac surgery center for emergency encounters, suggesting that in emergencies patients may be admitted to the nearest hospital, even if not a licensed cardiac surgery center. Our study identified that the important predictors for access and receipt of inpatient care at cardiac surgery centers are CHD severity, residence rurality, classification of encounter as surgical or nonsurgical, drive time, and teaching status of the hospital. We found a complex association between sociodemographic factors such as race/ethnicity and socioeconomic status, hospital level characteristics, and receipt of care at a cardiac surgery center.

There is increasing evidence that children with CHDs are at increased risk of morbidity, mortality, and resource utilization as compared to those without CHDs. Recent ACC/AHA guidelines recommend that all adult patients with CHDs, regardless of CHD severity or type of procedure, should receive all inpatient care at CHD centers. While there are no comparable guidelines that have been published for children with CHDs, prior investigations support the need for specialized care for all individuals with CHDs even in the setting of routine noncardiac admissions. The creation of specialized networks for all individuals with CHDs is supported by this evidence. Therefore, this investigation further explores the barriers for cardiac and noncardiac hospitalizations in children and young adults with CHD at specialized care centers. Our results are consistent with previous research in California, which found that adults with CHDs are less likely to receive care for outpatient noncardiac surgery at a CHD center.
Although we found that about 89% of individuals received cardiac care at cardiac surgery centers, only 30% of these visits occurred at the closest center. In our analysis this pattern was particularly pronounced for individuals in metropolitan NYC and other urban areas with a large number of high-volume hospitals. This suggests that individuals have a greater travel burden to receiving specialized cardiac care than necessary, particularly for cardiac encounters. CHD patients who travel farther than the closest hospital may prefer higher volume hospitals for better care quality or to satisfy insurance restrictions\(^37\). It follows that better regionalization of care via triage to a select few high-volume hospitals in population-dense areas may result in better quality of care than the proliferations of many small-volume centers in the same area.\(^37\), \(^38\) In an appropriately disseminated health system model, patients could be triaged at a smaller local hospital and those needing complicated specialty care could be referred to a better equipped hospital ideally with guidance from centralized specialists. Our sensitivity analysis for transfers suggests that many cases are transferred to distant hospitals that may be better equipped to provide CHD-specific care, such as a pediatric/adult cardiac surgery center.

As with our research, previous studies have found that distance is a significant barrier to accessing care at a CHD center in both the adult and pediatric CHD populations.\(^15\) Time required to travel to a cardiac surgery center is also an important contributor to disparities in care and familial burdens.\(^39\) A travel time standard of 30 minutes is considered appropriate for most medical encounters.\(^40\), \(^41\) The median drive times to the center where cardiac care was received (32 minutes) and to the closest cardiac surgery center (20 minutes) were just above and under this standard, but there were large differences in travel times between urban and rural areas. In the urban areas of NYC, travel times were modest, and all individuals had access to public transit. However, in other urban areas of NYS, median travel times were longer and only two-thirds of encounters occurred in areas with public transit availability. In rural areas, median drive times were over an hour and very few encounters occurred in areas where public transit was a viable option. Other studies have found that, for individuals with medical conditions requiring extended and specialized modalities of care, distance to specialized care was a burden even for individuals in urban or metropolitan areas.\(^22\), \(^42\), \(^43\) Longer travel times and distances to in-network providers also interfered with an individual (or their caregiver’s) ability to work.\(^44\), \(^45\) Extended travel time may be a substantial burden on the individual and his/her family, resulting in more time off work and lost pay. Increased travel time can contribute to high out-of-pocket expenses, financial problems, employment impact, and caregiving time, which are reported more often by families of individuals with CHDs.\(^39\) Such families were more likely to have stopped working/cut hours to care for child and/or spend greater time providing or coordinating health care visits as compared to other families with children with special health care needs.\(^39\) For children, the need to take time off from school for clinical appointments has also been associated with a reduced quality of life.\(^46\)

Proximity to care remains an important mediator for lack of access to specialized cardiac care in rural areas. Telemedicine or eHealth interventions such as home-monitoring, online disease-specific information, video conferencing and texting with providers may be especially useful for adolescents and adults with CHDs who need routine follow-up care and monitoring after hospitalization.\(^47\) In rural areas, telemedicine may allow for early
prehospital diagnosis through EKG and echo image transmission to a tertiary level center for a “second opinion,” thus alleviating burden of travel to a specialty care center. Telemedicine may also reduce gaps in care by allowing patient remote control through wearable devices, especially in conditions such as chronic heart failure or arrhythmias. However, equitable telemedicine requires that individuals have access to stable internet service and that interpreter services are available for populations who do not speak English, as these factors may limit accessibility in the most vulnerable. Making travel costs reimbursable and providing options for temporary housing support near hospitals may also help ease the travel burden for these individuals and their families. Increasing such options for routine care, having a medical home (a clinical setting that serves as a central resource for a patient’s ongoing medical care) and encouraging individuals with CHDs to remain in such routine care may result in better disease management due to care coordination and avoidance of unnecessary high cost, repetitive, or emergent interventions or hospitalizations.

In our analysis, we also found that access to care among those in rural residences improved relative to those in NYC after adjustment for teaching status and geographic proximity. This suggests that factors that contribute to hospital choice may be different in urban and rural areas.

Insurance remained a significant barrier to accessing specialized cardiac care; individuals with Medicaid or those who were uninsured were less likely to receive care at a cardiac surgery center. This may be due to restrictions on which insurance is accepted at each facility. Similar disparities have also been documented in other studies of high-need individuals requiring emergency department visits for adult congenital heart disease and pediatric neurosurgical care.

Disparities due to socio-economic status and race/ethnicity persisted for non-cardiac encounters, but similar disparities did not persist for cardiac encounters. Adjusting for individual level factors, non-Hispanic Blacks and those in high poverty census tracts were less likely to receive cardiac care at cardiac surgery centers than non-Hispanic whites and those in low poverty areas, but these were no longer significant after adjustment for encounter and center level factors. These findings may reflect the fact that most non-Hispanic Blacks in NYS reside in urban areas, especially NYC, which have more teaching hospitals and public transit options. Teaching hospitals are more likely to be large safety-net hospitals in urban areas that are more likely to provide care for urban poor, blacks, and Hispanics. Metropolitan teaching hospitals have also been shown to have significantly higher rates of admission compared with other hospital types for complex adult CHD.

As with any research using administrative data, our study has some limitations. We may have excluded individuals with CHDs whose diagnosis was not recorded for their inpatient encounter. Additionally, misclassification of CHDs can occur with use of ICD-9-CM codes. The use of administrative codes has several limitations, such as non-specificity of the codes themselves and the medical uncertainty in the assignment of the code. However, our exclusive use of inpatient admission data and a relatively young patient population likely improved the validity of CHD diagnoses, even for atrial septal defect and nonsevere codes.
Previous studies have found that a large proportion of CHD patients experience gaps in cardiac care in early adulthood, and those with gaps are more likely to present with more severe and symptomatic illness upon return to care. Further research is needed to delineate whether gaps in CHD care may increase burden of emergency care for such individuals. Our study focused on NYS during 2008–2013, which may limit the generalizability of our results for other states or time periods with different patterns of care. Specifically, our definition of specialized cardiac care was limited to licensed cardiac surgery centers in NYS and may not reflect all hospitals in the state with expertise in congenital heart disease. The mere presence of a cardiac surgical program for adults is not necessarily a marker for high quality/specialized adult CHD care. This means that the gaps in availability of specialized care may be even worse than what our conservative definition of “specialized” care in adults is able to capture. However, we sought to examine where CHD patients received inpatient care for which guidelines have advocated the availability of cardiac surgery. We were unable to identify non-cardiac surgical specialized centers in NYS. Since there were no criteria for specialized care centers for children or adults with CHD during the study period, our definitions are a surrogate for specialized care centers with the above limitations. The Adult Congenital Heart Association (ACHA) has recently started accreditation for adult congenital heart disease programs. While not a factor in this analysis of data from 2008 to 2013, future studies should examine ACHA accreditation as a factor associated with hospital preference.

We were unable to determine actual time of visit. Traffic patterns may vary by time of day and may impact drive time estimates. We therefore calculated drive time based on standard office hours (weekdays between 9 AM to 5 PM). We included all NYS addresses available for the individuals in the study; however, our database did not have information on out of state moves. Finally, socioeconomic status was derived from ACS census tract estimates and may not reflect actual socioeconomic status of the individuals. However, we expect that misclassification due to measurement error would be non-differential and have a minimal impact on our findings.

To our knowledge this is one of the first comprehensive assessments of inpatient care and barriers to specialized cardiac care among adolescents and adults with CHDs in NYS. We used statewide, population-based CHD surveillance data from a large, racially/ethnically diverse population insured by different health care payers. We integrated information from multiple Cardiac Surgery Reports to create a comprehensive list of specialized cardiac care centers across NYS at time of encounter for each individual. Finally, the study used rigorous GIS-based methods for determination of travel time in place of Euclidean or simple travel distance estimates. Euclidean and travel distance have been extensively used in previous literature; however, they do not account for traffic patterns, speed limits, and other factors besides distance that may impact an individual’s commute. Web mapping APIs, such as the Google Maps API used for this study, are becoming the more preferred option for transportation and healthcare access analyses because they can account for such factors and, therefore, provide a more realistic estimate of travel time. Information on public transit accessibility is rarely incorporated in studies of access to care. Inability to assess public transit time and traffic patterns has been identified as a limitation in other studies of geographic accessibility, because results are likely not generalizable to those who

*Am Heart J. Author manuscript; available in PMC 2022 June 01.*
prefer or rely on alternative modes of transportation. Public transit may be a preferred option in metropolitan areas such as NYC but may also be the only mode of travel for socioeconomically disadvantaged groups even in areas of lesser connectivity. We tapped into a comprehensive database of public transit data in NYS and found that outside of the well-connected metropolitan area of NYC, use of public transit is not a viable option for accessing care in most of the state.

In conclusion, this study suggests that GIS methods can be employed in studies of birth defects surveillance to provide information on barriers and burdens of accessing care, including travel time. Though a large majority of adolescents and adults in NYS access highly specialized cardiac care, significant differences exist, especially in rural areas, among individuals with less severe CHDs, and among those receiving nonsurgical or noncardiac care. Since most individuals with CHDs require lifelong cardiac care, patients and their caregivers should be counseled on the best available options for their special needs, especially if these have a significant travel burden.

**Supplementary Material**

Refer to Web version on PubMed Central for supplementary material.

**Acknowledgments**

The authors would like to thank Kimberly Cozzens (Program Manager at the New York State Cardiac Services Program) for her help with identifying cardiac centers and details on New York’s Cardiac Services. We also would like to thank Amandus Ankobil for his help with review and formatting of the article.

**Funding**

This publication was supported by the Cooperative Agreement numbers CK121202 (Emerging Infections Programs), DD151506 (Surveillance of Congenital Heart Defects Across the Lifespan), and EH171702 (Enhancing Innovation and Capabilities of the Environmental Public Health Tracking Network) funded by the Centers for Disease Control and Prevention. The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

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**Figure 1.**
Conceptual model showing individual, encounter, and hospital level factors that influence receipt of care at a cardiac surgery center

- Blue boxes denote factors amenable to intervention
- Dashed lines denote mediation effects
Figure 2.
Healthcare facilities visited by individuals with CHDs in New York State 2008–2013
Table I.
Characteristics of adolescents and young adults with congenital heart defects (CHDs) in New York with ≥1 hospitalization during 2008 to 2013

|                              | n (%)  |
|------------------------------|--------|
| Total cases                  | 4926   |
| Age (on January 1, 2013)     |        |
| 11–15                        | 1104 (22.4) |
| 16–20                        | 1141 (23.2) |
| 21–25                        | 1265 (25.7) |
| 26–30                        | 1416 (28.8) |
| Sex                          |        |
| Female                       | 2584 (52.5) |
| Male                         | 2342 (47.5) |
| Race/ethnicity               |        |
| White/non-Hispanic           | 2431 (49.4) |
| Black/non-Hispanic           | 745 (15.1) |
| Other/non-Hispanic           | 979 (19.9) |
| Hispanic Origin              | 762 (15.5) |
| Unknown/missing              | 9 (0.2) |
| Congenital heart defect severity |        |
| Nonsevere                    | 4285 (87.0) |
| Severe                       | 641 (13.0) |

We identified individuals with inpatient encounters who were between the ages of 11 and 30 as of January 1, 2013. In the case summary table, we include age as of Jan 1, 2013.
Table II.
Characteristics of 6,939 inpatient hospitalizations among 4,926 adolescents and young adults with congenital heart defects (CHDs) in New York, 2008 to 2013

| Hospitalization classification | Total N (%) | Cardiac/vascular n (%) | Noncardiac/vascular n (%) | P value |
|-------------------------------|-------------|------------------------|---------------------------|---------|
| Total                         | 6939 (100)  | 3136 (45.2)            | 3803 (54.8)               |         |
| Care received at age appropriate cardiac center |           |                        |                           |         |
| Yes                           | 4895 (70.5) | 2721 (86.8)            | 2174 (57.2)               | < .0001 |
| No                            | 2044 (29.5) | 415 (13.2)             | 1629 (42.8)               |         |
| Age at encounter (in years) * |           |                        |                           |         |
| < 11                          | 565 (8.1)  | 317 (10.1)             | 248 (6.5)                 | < .0001 |
| 11–15                         | 1458 (21.0)| 730 (23.3)             | 728 (19.1)                |         |
| 16–20                         | 1680 (24.2)| 773 (24.7)             | 907 (23.9)                |         |
| 21–25                         | 1848 (26.6)| 748 (23.9)             | 1100 (28.9)               |         |
| 26–30                         | 1343 (19.4)| 560 (17.9)             | 783 (20.6)                |         |
| > 30                          | 45 (0.7)   | 8 (0.3)                | 37 (1.0)                  |         |
| Insurance Type                |           |                        |                           | < .0001 |
| Private/Commercial            | 4787 (69.0)| 2360 (75.3)            | 2427 (63.8)               |         |
| Medicaid                      | 1442 (20.8)| 487 (15.5)             | 955 (25.1)                |         |
| Medicare                      | 252 (3.6)  | 71 (2.3)               | 181 (4.8)                 |         |
| Self-pay/Uninsured            | 277 (4.0)  | 143 (4.6)              | 134 (3.5)                 |         |
| Other                         | 160 (2.3)  | 66 (2.1)               | 94 (2.5)                  |         |
| Unknown                       | 21 (0.3)   | 9 (0.3)                | 12 (0.3)                  |         |
| Admission Type                |           |                        |                           | < .0001 |
| Emergency                     | 3548 (51.1)| 1165 (37.2)            | 2383 (62.7)               |         |
| Urgent                        | 798 (11.5) | 278 (8.9)              | 520 (13.7)                |         |
| Elective                      | 2566 (37.0)| 1679 (53.5)            | 887 (23.3)                |         |
| Other                         | 6 (0.1)    | 1 (0.0)                | 5 (0.1)                   |         |
| Unknown                       | 21 (0.3)   | 13 (0.4)               | 8 (0.2)                   |         |
| Surgical procedure performed  |           |                        |                           | < .0001 |
| Yes                           | 2812 (40.5)| 1949 (62.2)            | 863 (22.7)                |         |
We identified individuals with inpatient encounters who were between the ages of 11 and 30 as of January 1st, 2013. In the encounter summary, we include age at the time of the encounter. There may be individuals who were younger or older than the specified age range at different points in the surveillance period. Abbreviations: APR DRG = All Patient Refined Diagnosis Related Group.
Table III.
Prevalence ratio (PR) estimates and 95% confidence intervals (95% CI) for the association between receiving care at a cardiac surgical care center and selected individual, encounter and center level characteristics, among cardiac encounters, 2008 to 2013

|                              | Unadjusted | Model 1 PR (95% CI) | Model 2† PR (95% CI) | Model 3‡ PR (95% CI) |
|------------------------------|------------|----------------------|----------------------|----------------------|
| Sex                          |            |                      |                      |                      |
| Female                       | 1 (Reference) | 1 (Reference)        | 1 (Reference)        | 1 (Reference)        |
| Male                         | 0.99 (0.97–1.01) | 0.99 (0.96–1.01)    | 0.99 (0.97–1.01)    | 1.00 (0.97–1.02)    |
| Race/ethnicity               |            |                      |                      |                      |
| White/Non-Hispanic           | 1 (Reference) | 1 (Reference)        | 1 (Reference)        | 1 (Reference)        |
| Black/Non-Hispanic           | 0.96 (0.93–1.00) | 0.94 (0.91–0.98)    | 0.99 (0.95–1.03)    | 0.98 (0.94–1.02)    |
| Other/Non-Hispanic           | 1.02 (0.98–1.05) | 1.00 (0.97–1.03)    | 1.02 (0.99–1.05)    | 1.01 (0.98–1.04)    |
| Hispanic origin              | 0.99 (0.96–1.03) | 0.98 (0.94–1.02)    | 1.00 (0.96–1.04)    | 0.98 (0.95–1.02)    |
| Congenital heart defect severity |           |                      |                      |                      |
| Non-severe                   | 1 (Reference) | 1 (Reference)        | 1 (Reference)        | 1 (Reference)        |
| Severe                       | 1.07 (1.04–1.10) | 1.07 (1.04–1.10)    | 1.07 (1.04–1.10)    | 1.05 (1.02–1.08)    |
| Census tract poverty         |            |                      |                      |                      |
| Low                          | 1 (Reference) | 1 (Reference)        | 1 (Reference)        | 1 (Reference)        |
| High                         | 0.99 (0.97–1.02) | 0.97 (0.94–1.00)    | 0.98 (0.96–1.01)    | 1.00 (0.97–1.03)    |
| Region/Census tract rurality |            |                      |                      |                      |
| NYC                          | 1 (Reference) | 1 (Reference)        | 1 (Reference)        | 1 (Reference)        |
| Non-NYC, Urban               | 0.93 (0.87–0.99) | 0.95 (0.92–0.97)    | 0.95 (0.92–0.97)    | 1.00 (0.97–1.03)    |
| Non-NYC, Rural               | 0.96 (0.94–0.99) | 0.90 (0.84–0.97)    | 0.93 (0.87–1.00)    | 1.14 (1.06–1.23)    |
| Age at encounter (years)     |            |                      |                      |                      |
| < 16                         | 1 (Reference) | 1 (Reference)        | 1 (Reference)        | 1 (Reference)        |
| 16–20                        | 0.95 (0.92–0.98) | 0.96 (0.92–0.99)    | 0.98 (0.95–1.01)    | 0.98 (0.95–1.01)    |
| 21–25                        | 0.96 (0.93–0.99) | 1.02 (0.98–1.06)    | 1.01 (0.97–1.05)    | 0.98 (0.95–1.03)    |
| > 25                         | 0.93 (0.90–0.97) | 0.96 (0.92–0.99)    | 1.03 (1.00–1.07)    | 1.00 (0.97–1.03)    |
| Insurance type               |            |                      |                      |                      |
| Private/Commercial           | 1 (Reference) | 1 (Reference)        | 1 (Reference)        | 1 (Reference)        |
| Medicaid                     | 0.90 (0.87–0.93) | 0.95 (0.91–0.98)    | 0.95 (0.92–0.99)    | 0.95 (0.92–0.99)    |
| Medicare                     | 0.94 (0.87–1.02) | 0.95 (0.88–1.04)    | 0.97 (0.90–1.05)    | 0.97 (0.90–1.05)    |
|                                      | Unadjusted | Model 1 PR (95% CI) | Model 2 † PR (95% CI) | Model 3 ‡ PR (95% CI) |
|--------------------------------------|------------|---------------------|-----------------------|-----------------------|
| Self-pay/Uninsured                   | 0.83 (0.76–0.91) | 0.87 (0.82–0.93) | 0.90 (0.84–0.96) |                      |
| Other                                | 0.80 (0.75–0.85) | 0.88 (0.81–0.97) | 0.88 (0.80–0.96) |                      |
| Admission type                       |            |                     |                       |                      |
| Emergency                            | 1 (Reference) | 1 (Reference) | 1 (Reference) |                      |
| Urgent                               | 1.19 (1.14–1.24) | 1.14 (1.09–1.19) | 1.14 (1.09–1.20) |                      |
| Elective                             | 1.28 (1.25–1.32) | 1.14 (1.10–1.19) | 1.14 (1.09–1.18) |                      |
| Surgical encounter                   |            |                     |                       |                      |
| Yes                                  | 1 (Reference) | 1 (Reference) | 1 (Reference) |                      |
| No                                   | 0.78 (0.76–0.80) | 0.84 (0.81–0.87) | 0.88 (0.85–0.91) |                      |
| Severity of illness                  |            |                     |                       |                      |
| Minor                                | 1 (Reference) | 1 (Reference) | 1 (Reference) |                      |
| Moderate                             | 0.96 (0.94–0.99) | 1.03 (1.00–1.06) | 1.03 (1.00–1.06) |                      |
| Major                                | 1.03 (0.99–1.06) | 1.05 (1.01–1.08) | 1.04 (1.01–1.08) |                      |
| Extreme                              | 1.01 (0.96–1.07) | 1.04 (0.98–1.10) | 1.04 (0.98–1.10) |                      |
| Log time to closest age-appropriate cardiac center (mins) | 0.93 (0.91–0.95) | | | 0.92 (0.90–0.94) |
| Teaching hospital                    |            |                     |                       |                      |
| Yes                                  | 3.65 (3.26–4.09) | | | 3.19 (2.85–3.58) |
| No                                   | 1 (Reference) | | | 1 (Reference) |

CI = confidence interval; NYC = New York City; PR = prevalence ratio.

* Defined as receiving care at a center approved to perform pediatric cardiac surgery for individuals ages 5 to 18 years and at any center approved to perform cardiac surgery for individuals ages 19 to 31 years.

† Includes encounter level variables (surgical/non-surgical classification, admission type, severity of illness and insurance).

‡ Includes center level variables (travel time and teaching status).
Table IV.
Prevalence ratio (PR) estimates and 95% confidence intervals (95% CI) for the association between receiving care at a cardiac surgical care center and selected individual, encounter and center level characteristics, among non-cardiac encounters, 2008–2013

|                        | Unadjusted PR (95% CI) | Model 1 PR (95% CI) | Model 2 PR (95% CI) | Model 3 PR (95% CI) |
|------------------------|------------------------|---------------------|---------------------|---------------------|
| Sex                    |                        |                     |                     |                     |
| Female                 | 1 (Reference)          | 1 (Reference)       | 1 (Reference)       | 1 (Reference)       |
| Male                   | 0.96 (0.91–1.01)       | 0.96 (0.92–1.01)    | 1.02 (0.97–1.08)    | 1.02 (0.97–1.07)    |
| Race/Ethnicity         |                        |                     |                     |                     |
| White/Non-Hispanic     | 1 (Reference)          | 1 (Reference)       | 1 (Reference)       | 1 (Reference)       |
| Black/Non-Hispanic     | 1.02 (0.95–1.09)       | 0.97 (0.90–1.05)    | 1.02 (0.94–1.10)    | 0.84 (0.78–0.91)    |
| Other/Non-Hispanic     | 1.15 (1.08–1.22)       | 1.06 (0.99–1.14)    | 1.09 (1.02–1.17)    | 0.98 (0.92–1.05)    |
| Hispanic Origin        | 1.10 (1.02–1.19)       | 1.04 (0.96–1.13)    | 1.08 (0.99–1.17)    | 0.93 (0.86–1.00)    |
| Congenital heart defect severity |                     |                     |                     |                     |
| Non-severe             | 1 (Reference)          | 1 (Reference)       | 1 (Reference)       | 1 (Reference)       |
| Severe                 | 1.08 (1.01–1.15)       | 1.09 (1.02–1.17)    | 1.10 (1.03–1.18)    | 1.04 (0.98–1.11)    |
| Census tract poverty   |                        |                     |                     |                     |
| High                   | 0.98 (0.93–1.03)       | 0.92 (0.87–0.97)    | 0.93 (0.87–0.98)    | 0.94 (0.89–1.00)    |
| Low                    | 1 (Reference)          | 1 (Reference)       | 1 (Reference)       | 1 (Reference)       |
| Region/Census tract rurality |                   |                     |                     |                     |
| NYC                    | 1 (Reference)          | 1 (Reference)       | 1 (Reference)       | 1 (Reference)       |
| Non-NYC, Urban         | 0.88 (0.84–0.93)       | 0.87 (0.82–0.92)    | 0.87 (0.82–0.92)    | 1.09 (1.03–1.16)    |
| Non-NYC, Rural         | 0.61 (0.52–0.70)       | 0.59 (0.51–0.69)    | 0.60 (0.52–0.70)    | 1.49 (1.29–1.73)    |
| Age group (years)      |                        |                     |                     |                     |
| < 16                   | 1 (Reference)          | 1 (Reference)       | 1 (Reference)       | 1 (Reference)       |
| 16–20                  | 1.00 (0.92–1.07)       | 1.02 (0.94–1.10)    | 0.98 (0.92–1.06)    |                     |
| 21–25                  | 1.22 (1.14–1.31)       | 1.28 (1.19–1.37)    | 1.07 (1.00–1.15)    |                     |
| > 25                   | 1.26 (1.17–1.35)       | 1.31 (1.22–1.41)    | 1.08 (1.00–1.16)    |                     |
| Insurance type         |                        |                     |                     |                     |
| Private/Commercial     | 1 (Reference)          | 1 (Reference)       | 1 (Reference)       | 1 (Reference)       |
| Medicaid               | 0.88 (0.82–0.93)       | 0.87 (0.82–0.93)    | 0.92 (0.87–0.98)    |                     |
| Medicare               | 1.02 (0.92–1.14)       | 0.92 (0.82–1.04)    | 1.07 (0.96–1.20)    |                     |
|                      | Unadjusted | Model 1 PR (95% CI) | Model 2† PR (95% CI) | Model 3‡ PR (95% CI) |
|----------------------|------------|---------------------|----------------------|---------------------|
| Self-pay/Uninsured   | 0.61 (0.51–0.73) | 0.62 (0.52–0.74) | 0.77 (0.65–0.92) |
| Other                | 1.23 (1.06–1.43) | 1.32 (1.14–1.54) | 1.21 (1.04–1.39) |
| Admission type       |             |                     |                      |                     |
| Emergency            | 1 (Reference) | 1 (Reference) | 1 (Reference) | |
| Urgent               | 1.12 (1.04–1.20) | 1.11 (1.03–1.19) | 1.09 (1.02–1.17) | |
| Elective             | 1.16 (1.09–1.23) | 1.13 (1.06–1.21) | 1.16 (1.09–1.23) | |
| Surgical procedure performed |             |                     |                      |                     |
| Yes                  | 1 (Reference) | 1 (Reference) | 1 (Reference) | |
| No                   | 0.88 (0.83–0.93) | 0.90 (0.85–0.96) | 0.96 (0.90–1.02) | |
| Severity of illness  |             |                     |                      |                     |
| Minor                | 1 (Reference) | 1 (Reference) | 1 (Reference) | |
| Moderate             | 1.09 (1.08–1.20) | 1.11 (1.00–1.22) | 1.05 (0.96–1.16) | |
| Major                | 1.24 (1.12–1.37) | 1.25 (1.13–1.40) | 1.19 (1.08–1.31) | |
| Extreme              | 1.25 (1.10–1.41) | 1.32 (1.16–1.50) | 1.24 (1.10–1.40) | |
| Log time to closest age-appropriate cardiac center (minutes) | 0.73 (0.71–0.75) | | 0.71 (0.68–0.74) | |
| Center where care received |             |                     |                      |                     |
| Non-Teaching         | 1 (Reference) | 1 (Reference) | | |
| Teaching             | 7.41 (6.32–8.68) | | 6.37 (5.46–7.43) | |

CI = confidence interval; NYC = New York City; PR = prevalence ratio.

*Defined as receiving care at a center approved to perform pediatric cardiac surgery for individuals ages 5–18 years and at any center approved to perform cardiac surgery for individuals ages 19 to 31 years.

†Includes encounter level variables (APR DRG, Admission type, severity of illness and insurance).

‡Includes hospital level variables (travel time and teaching status).
Table V.

One-way drive time and one-way public transit time from residential address to care center for cardiac and noncardiac hospitalizations, SPARCS 2008–2013

| Proximity to center where care was received | Proximity to closest cardiac surgical care center†‡ |
|-------------------------------------------|-----------------------------------------------|
|                                            | One-way drive time (mins) | With public transit n (%) | One-way public transit time (mins) | With public transit n (%) | One-way drive time (mins) | With public transit n (%) | One-way public transit time (mins) |
|                                            | median (range)             |                          | median (range)                     |                          | median (range)             |                          | median (range)                     |
| Overall                                    | 32.2 (0.5–331.8)           | 2456 (78.3)              | 62.0 (0.3–724.3)                   | 20.3 (0.5–199.7)         | 2489 (79.4)                | 42.8 (0.3–443.2)           |
| Region                                     |                             |                          |                                    |                            |                            |                            |                                   |
| NYC                                        | 29.0 (0.9–170.1)           | 1599 (99.8)              | 53.6 (0.3–317.0)                   | 17.7 (0.8–67.5)          | 1603 (100.0)              | 35.3 (0.3–120.8)           |
| Non-NYC, Urban                             | 36.5 (0.5–331.8)           | 846 (59.5)               | 89.8 (0.9–724.3)                   | 23.9 (0.5–118.3)         | 878 (61.7)                | 65.6 (0.9–443.2)           |
| Non-NYC, Rural                             | 78.9 (2.2–285.4)           | 11 (9.9)                 | 30.5 (9.5–334.0)                   | 67.9 (2.1–199.7)         | 8 (7.2)                   | 82.4 (9.5–318.0)           |
| Census tract poverty                       |                             |                          |                                    |                            |                            |                                    |
| High †                                     | 25.7 (2.2–228.9)           | 1026 (96.1)              | 49.1 (2.4–403.3)                   | 17.8 (1.8–199.7)         | 1028 (96.3)              | 34.1 (2.4–253.5)           |
| Low ‡                                      | 35.6 (0.5–331.8)           | 1430 (69.1)              | 74.1 (0.3–724.3)                   | 21.8 (0.5–152.2)         | 1461 (70.6)              | 50.8 (0.3–443.2)           |
| Non-cardiac hospitalizations               |                             |                          |                                    |                            |                            |                                    |
| Overall                                    | 20.7 (0.1–384.6)           | 2862 (75.3)              | 46.0 (1.8–749.4)                   | 20.5 (1.3–196.5)         | 2906 (76.4)              | 40.9 (2.7–749.4)           |
| Region                                     |                             |                          |                                    |                            |                            |                                    |
| NYC                                        | 20.1 (0.1–384.6)           | 1566 (99.6)              | 38.2 (1.8–619.6)                   | 17.1 (1.8–78.2)          | 1572 (99.9)              | 31.5 (3.1–125.1)           |
| Non-NYC, Urban                             | 20.4 (1.3–318.6)           | 1262 (61.8)              | 57.6 (3.9–749.4)                   | 23.7 (1.3–113.8)         | 1324 (64.8)              | 60.8 (2.7–749.4)           |
| Non-NYC, Rural                             | 45.3 (2.1–314.3)           | 34 (18.1)                | 25.3 (7.0–396.5)                   | 76.6 (13.6–196.5)        | 10 (5.3)                 | 109.9 (66.8–396.5)         |
| Census tract poverty                       |                             |                          |                                    |                            |                            |                                    |
| High †                                     | 15.8 (1.3–384.6)           | 1337 (92.8)              | 33.4 (2.1–619.6)                   | 17.1 (1.8–196.5)         | 1323 (91.9)              | 31.4 (3.1–241.7)           |
| Low ‡                                      | 23.3 (0.1–318.6)           | 1525 (64.5)              | 60.0 (1.8–749.4)                   | 22.6 (1.3–151.1)         | 1583 (67.0)              | 53.8 (2.7–749.4)           |

NYC = New York City; SPARCS = Statewide Planning and Research Cooperative System.

For both cardiac and non-cardiac hospitalizations, differences in one-way drive times and one-way transit times across region and census tract strata are statistically significant at the group level. Select statistically significant pairwise differences have been highlighted in the text.

* ≥20% of population living at or below the Federal Poverty Level.

† < 20% of population living at or below the Federal Poverty Level.
