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Neighborhood Income Is Associated with Health Care Use in Pediatric Short Bowel Syndrome

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Objective To evaluate associations between neighborhood income and burden of hospitalizations for children with short bowel syndrome (SBS).

Study design We used the Pediatric Health Information System (PHIS) database to evaluate associations between neighborhood income and hospital readmissions, readmissions for central line–associated bloodstream infections (CLABSI), and hospital length of stay (LOS) for patients <18 years with SBS hospitalized between January 1, 2006, and October 1, 2015. We analyzed readmissions with recurrent event analysis and analyzed LOS with linear mixed effects modeling. We used a conceptual model to guide our multivariable analyses, adjusting for race, ethnicity, and insurance status.

Results We included 4289 children with 16 347 hospitalizations from 43 institutions. Fifty-seven percent of the children were male, 21% were Black, 19% were Hispanic, and 67% had public insurance. In univariable analysis, children from low-income neighborhoods had a 38% increased risk for all-cause hospitalizations (rate ratio [RR] 1.38, 95% CI 1.10-1.72, $P = .01$), an 83% increased risk for CLABSI hospitalizations (RR 1.83, 95% CI 1.37-2.44, $P < .001$), and increased hospital LOS (β 0.15, 95% CI 0.01-0.29, $P = .04$). In multivariable analysis, the association between low-income neighborhoods and elevated risk for CLABSI hospitalizations persisted (RR 1.70, 95% CI 1.23-2.35, $P < .01$, respectively).

Conclusions Children with SBS from low-income neighborhoods are at increased risk for hospitalizations due to CLABSI. Examination of specific household- and neighborhood-level factors contributing to this disparity may inform equity-based interventions. *(J Pediatr 2024;265:113819)*.

Short bowel syndrome (SBS) is characterized by severely reduced bowel length or a prolonged need for parenteral nutrition after intestinal resection.[1,2] Administering parenteral nutrition is a complex medical intervention fraught with complications, including central line–associated bloodstream infections (CLABSI), venous thrombosis, and liver disease.[1] Due to the complex and chronic nature of this disease, children with SBS are at high risk for morbidity, mortality, and reduced quality of life.[1,3,4]

Health disparities are well documented in many chronic pediatric illnesses.[5-7] In addition to racial and ethnic disparities, a growing body of literature demonstrates associations between socioeconomic status (SES) and health, with lower SES being associated with worse health outcomes.[6-10] In pediatric SBS, previous work has established that children of color are more likely to die from SBS.[11] However, there is limited research exploring the impact of SES on health outcomes in SBS. Although one study has identified that high income and private insurance are protective against risk of 30-day readmission, few other studies have explored the impact of SES on health outcomes in SBS.[12] Further, there are no studies that characterize disparities in health care use across multiple hospitalizations in pediatric SBS.

Neighborhood-level measures of SES have been associated with adverse health outcomes in many chronic pediatric diseases.[8-10,13,14] Neighborhood-level SES contextualizes a child's living environment and may provide additional insight into a child's living conditions and neighborhood socioeconomic resources. In the absence of more robust individual social risk data, which are rarely available in administrative databases, these measures may more closely approximate one's SES above what insurance type can provide. Particularly for children with SBS, the care they receive may be affected by these neighborhood

CLABSI	Central line–associated bloodstream infection
ELP	Ethanol-lock prophylaxis
HHI	Median household income of patient's home ZIP code
ICD-9-CM	*International Classification of Diseases, Ninth Revision, Clinical Modification*
LOS	Length of stay
PHIS	Pediatric Health Information System
RR	Rate ratio
SBS	Short bowel syndrome
SES	Socioeconomic status

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factors, including the presence of home health nursing and access to reliable transportation. Thus, neighborhood-level data such as neighborhood income can provide valuable information on the socioeconomic milieu in which a child with SBS lives. To our knowledge, there are no studies evaluating the role of neighborhood-level measures of SES on health outcomes in SBS. We hypothesized that living in a low-income neighborhood is associated with increased hospitalizations and longer lengths of stay (LOS) in the hospital for children with SBS. We evaluated the impact of neighborhood income on health care use for children with SBS.

Methods

Data Source

We used data from the Pediatric Health Information System (PHIS) database, which contains health care use data from 52 not-for profit, tertiary care, freestanding children's hospitals in the US. The PHIS was developed by the Children's Hospital Association and contains administrative encounter-level patient data from inpatient, observation, ambulatory, and emergency department encounters. For each encounter, PHIS includes patient-level demographic data, *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) diagnostic and procedural codes, and LOS. A key strength of PHIS is that participant records are linked across hospitalizations, enabling longitudinal study of patients across hospital encounters. The PHIS captures a substantial proportion of pediatric hospitalizations in the US, as hospitalizations within the PHIS database account for 20% of pediatric hospitalizations nationwide.[13]

Study Participants

There is no ICD-9-CM code for SBS. We therefore identified hospitalizations for patients with SBS using a previously employed combination of 2 ICD-9-CM codes: diagnostic code 579.3 (other and unspecified postsurgical nonabsorption) and procedural code 99.15 (parenteral infusion of concentrated nutrition substances).[15] We included patients aged younger than 18 years with ICD-9-CM codes for SBS and followed patients prospectively. We included patients whose index hospitalization occurred between January 1, 2006, and October 1, 2015 (n = 4289). We included all inpatient and observation hospitalizations and excluded all outpatient and emergency department visits.

Primary Outcome

Our primary outcome was recurrent hospitalizations during the study period. We also performed an analysis on the subset of hospitalizations attributed to CLABSI, as we hypothesized that these hospitalizations might more closely reflect household challenges with self-management. We also assessed the total LOS for each hospitalization as a secondary outcome.

Primary Exposure

Our primary exposure was neighborhood income, calculated as the median household income of the patient's home ZIP code (HHI) from 2010 US Census Data, and based on the patient's home ZIP code at time of initial hospitalization. This measure approximates household SES.[13,16] We classified patient hospitalizations into 4 categories of HHI based on previously described household income cut-offs.[13] HHI-1 represents the lowest-income neighborhoods, HHI-2 and HHI-3 represent medium-income neighborhoods, and HHI-4 represents the highest neighborhood income group.[13]

Statistical Analysis

We used a causal inference approach and constructed a directed acyclic graph to identify potential confounders for the relationship between neighborhood SES and our outcomes (**Figure 1**). We conceptualized race and ethnicity as social constructs that measure structural inequities experienced by minoritized racial and ethnic groups.[14] PHIS includes race and ethnicity information provided by participating institutions. However, the specific method of data collection across participating hospitals, whether through self-identification, extraction from maternal medical record, or other means, is not detailed. We classified participant race as "Black," "White," and "Other." We classified participant ethnicity as "Hispanic" or "not Hispanic." To examine disparities across racial and ethnic groups, we selected "White" and "not Hispanic" as the reference groups in our multivariable models, as these populations are often associated with greater levels of privilege and access to resources. We understood insurance status (private, public, and other) as a measure of individual SES.

To examine the association between HHI and risk of hospitalization, we used the proportional rate model with robust variance estimation. This method is an extension of Cox regression for analyzing recurrent events and enables modeling of the expected number of hospitalizations over time. We set the index hospitalization as time zero and modeled hospitalizations over the study period of January 1, 2006, to October 1, 2015. We censored patients on their date of death, 18th birthday, or at the end of the study period (October 1, 2015), whichever occurred first. We hypothesized that CLABSI admissions may more directly reflect barriers to self-management. Therefore, we performed the same method of analysis on the subset of hospitalizations attributed to CLABSI.

To model the relationship between HHI and LOS, we performed univariate and multivariate analysis using linear mixed effects with a subject-specific random intercept model. We log transformed LOS, as our LOS data were not normally distributed.

Statistical analyses were performed using Stata, version 17 (StataCorp LLC). We considered $P < .05$ as statistically significant. This study was deemed exempt by the University of California, San Francisco Institutional Review Board.

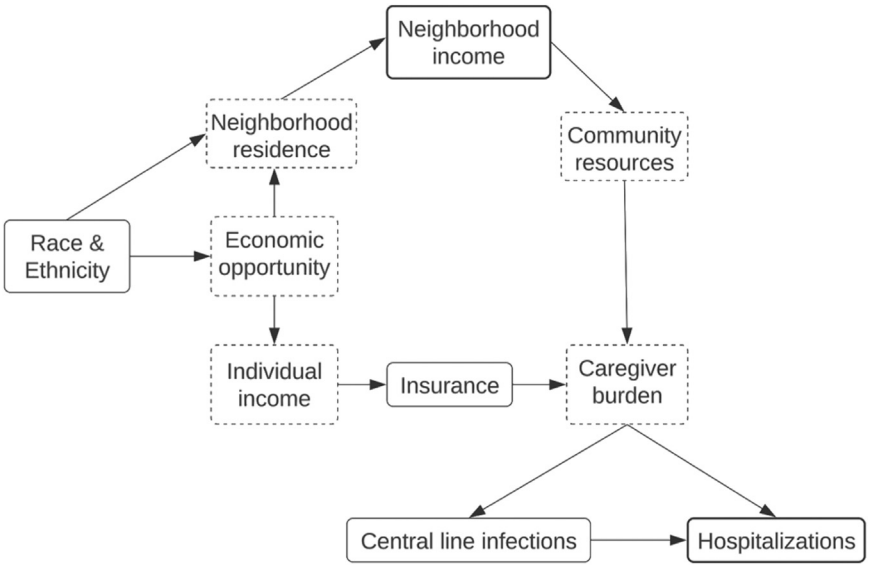

Figure 1. Directed acyclic graph representing our proposed causal model for the impact of neighborhood income on hospitalizations. *Bolded solid borders* represent our primary exposure, neighborhood income, and primary outcome, hospitalizations. *Solid borders* represent variables measurable in PHIS. *Dashed borders* represent unmeasurable variables that are not accessible in PHIS. We hypothesized that low neighborhood income results in increased caregiver burden. We hypothesized that increased caregiver burden increases risk for central-line infections and contributes to hospitalizations. Individual income is included in our model, as insurance status can determine access to medical services (ie, home health nursing), which will affect caregiver burden.

Results

Patient Characteristics

Our final cohort included 4289 patients with 16 347 hospitalizations across 43 children's hospitals. **Table I** depicts patient demographics. Fifty-seven percent of the sample was male, 21% Black, 19% Hispanic, and 67% of the sample had public insurance. The most common admission diagnoses were fever (25%), central-line infection, bacteremia, or sepsis (14%), and other and unspecified postsurgical nonabsorption (10%). CLABSI was the principal discharge diagnosis for 31% of hospitalizations.

The neighborhood income ranged from $6320 to $174 890 (median $39 178, IQR $31 385, $49 901). Patients from low-income neighborhoods (HHI-1) were more likely to be Black, Hispanic, have public insurance, and live in the Southern US.

All-Cause Hospitalizations

Of the 4289 patients, 2153 (50%) were readmitted during the study period. In univariable analysis (**Table II**), patients in low-income neighborhoods (HHI-1) had an increased rate of hospitalizations relative to the most affluent group, HHI-4 (rate ratio [RR] 1.38, 95% CI 1.10-1.72, $P = .01$). Hispanic ethnicity was not associated with a greater hospitalization rate compared with non-Hispanic ethnicity (RR 1.10, 95% CI 0.96-1.26, $P = .17$).

In multivariable analysis adjusting for race, ethnicity, and insurance status, HHI-1 was no longer associated with an increased risk of all-cause hospitalizations (RR 1.26, 95% CI 1.10-1.72, $P = .06$) (**Table II**). Public insurance was associated with an increased risk of hospitalizations compared with private insurance (RR 1.52, 95% CI 1.31-1.76, $P < .001$).

CLABSI Hospitalizations

A total of 1550 patients were hospitalized for CLABSI with a total of 5127 CLABSI hospitalizations. In univariable analysis (**Table II**), HHI-1 and HHI-2 were associated with an increased rate of CLABSI hospitalization compared with the most affluent group, HHI-4 (HHI-1: RR 1.83, 95% CI 1.37-2.44, $P < .001$; HHI-2: RR 1.65, 95% CI 1.24-2.20, $P < .01$). Black patients had an elevated CLABSI hospitalization rate compared with White patients (RR 1.20, 95% CI 1.03-1.39, $P = .02$). We did not find a statistically significant association between Hispanic ethnicity and risk for CLABSI hospitalizations (RR 1.17, 95% CI 0.99-1.40, $P = .07$).

In multivariable analysis, HHI-1 was associated with an increased rate of CLABSI hospitalization compared with HHI-4 (RR 1.70, 95% CI 1.23-2.35, $P < .01$). We did not find a statistically significant association between Black race or Hispanic ethnicity and risk for CLABSI hospitalizations (RR 1.18, 95% CI 0.98-1.43, $P = .08$ and RR 1.10, 95% CI 0.93-1.31, $P = .27$, respectively). **Figure 2** depicts the cumulative expected number of all-cause hospitalizations and CLABSI hospitalizations by neighborhood income group.

Table I. Demographic characteristics for patients* with SBS, with comparison of neighborhood income (HHI-1 vs HHI 2-4)

Characteristics	Total cohort, No. (%)	Neighborhood income		*P* value
		HHI-1: Median annual HHI of ZIP code <$33 075, No. (%)	HHI-2-4: Median annual HHI of ZIP code ≥$33 075, No. (%)	
Total patients	4289 (100%)	1274	3015	
Age at initial presentation, y				.33
<1	2836 (66%)	866 (68%)	1970 (65%)	
1-4	859 (20%)	248 (20%)	611 (20%)	
5-12	376 (9%)	102 (8%)	274 (9%)	
>12	218 (5%)	58 (5%)	160 (5%)	
Sex				.94
Female	1841 (43%)	548 (43%)	1293 (43%)	
Male	2448 (57%)	726 (57%)	1722 (57%)	
Region of US				<.001
Midwest	1097 (26%)	282 (22%)	815 (27%)	
Northeast	1097 (26%)	363 (29%)	734 (24%)	
South	1289 (30%)	438 (34%)	851 (28%)	
West	806 (19%)	191 (15%)	615 (20%)	
Race				<.001
White	2400 (56%)	651 (51%)	1749 (58%)	
Black	912 (21%)	350 (28%)	562 (19%)	
Other	829 (19%)	240 (19%)	589 (20%)	
Missing	148 (3%)	33 (3%)	115 (4%)	
Ethnicity				.002
Hispanic	833 (19%)	281 (22%)	552 (18%)	
Non-Hispanic	2473 (58%)	684 (54%)	1789 (59%)	
Missing	983 (23%)	309 (24%)	674 (22%)	
Insurance				<.001
Private	1130 (26%)	205 (16%)	925 (31%)	
Public	2894 (67%)	995 (78%)	1899 (63%)	
Other	265 (6%)	74 (6%)	191 (6%)	

*Demographic data extracted from first hospitalization per patient.

Length of Stay

In univariable analysis, children from the lowest income neighborhoods, HHI-1, had increased LOS compared with HHI-4 (HHI-1: β 0.15, 95% CI 0.01-0.29, P = .04) (Table III). Black children had increased LOS compared with White children (β 0.29, 95% CI 0.21-0.37, P < .001).

In multivariable analysis, we did not find a statistically significant association between HHI-1 and LOS (β 0.15, 95% CI –0.01 to 0.31, P = .06). Black children had increased length of stay compared with White children (β 0.26, 95% CI 0.17-0.35, P < .001).

Discussion

Evaluation of disparities in health care use for children with SBS across multiple hospitalizations has not been addressed previously. We uncovered socioeconomic and racial disparities in the number of hospital readmissions and in hospital LOS. Specifically, we found that children living in low-income neighborhoods are at increased risk for hospitalizations due to CLABSI, which are a potentially preventable cause of hospitalizations. Indeed, compared with wealthier neighborhoods, low-income neighborhoods were associated with an 83% increased risk of hospital readmission for CLABSI, representing a 2-fold increase in hospitalizations for CLABSI over the study period.

Mortality from SBS has improved substantially in the past 20 years.[1,17,18] However, as mortality rates have decreased, there has not been a significant improvement in the rates of children achieving enteral autonomy.[18] As a result, a substantial proportion of children with SBS are dependent on parenteral nutrition and must maintain central venous access for years.[18] Caregivers of these children must access central lines frequently and are tasked with the challenging duty of maintaining stringent hygiene to avoid introducing infection.

Our main finding was that children with SBS living in low-income neighborhoods have an increased risk for CLABSI hospitalizations, even after adjusting for insurance status, race, and ethnicity. This suggests that socioeconomic factors above and beyond insurance type affect management of the central line in SBS. This study lays the groundwork for future studies to characterize how neighborhood-level (eg, availability of shift nursing support in neighborhoods deemed unsafe, school-based medical resources) and household-level factors (eg, financial strain, transportation access) contribute to SBS outcomes. In addition, given that neighborhood deprivation has been associated with increased risk of prematurity, we suggest future work assess the extent to which prematurity mediates the relationship between neighborhood environment and SBS outcomes.[19,20]

Table II. Univariable and multivariable time-to-event analysis with Cox proportional rate of all-cause hospitalizations and CLABSI hospitalizations

	All-cause hospitalizations n = 4289						CLABSI hospitalizations n = 4289					
	Univariable analysis			Multivariable analysis			Univariable analysis			Multivariable analysis		
Variable	RR	CI	*P* value	RR	CI	*P* value	RR	CI	*P* value	RR	CI	*P* value
Neighborhood income												
HHI-4	REF			REF			REF			REF		
HHI-3	1.20	0.96-1.50	.10	1.14	0.89-1.45	.29	1.29	0.97-1.72	.08	1.22	0.88-1.67	.23
HHI-2	1.28	1.03-1.60	.03	1.18	0.93-1.50	.17	1.65	1.24-2.20	<.01	1.55	1.12-2.15	<.01
HHI-1	1.38	1.10-1.72	.01	1.26	0.99-1.61	.06	1.83	1.37-2.44	<.001	1.70	1.23-2.35	<.01
Insurance												
Private	REF			REF			REF			REF		
Public	1.58	1.39-1.81	<.001	1.52	1.31-1.76	<.001	1.70	1.42-2.04	<.001	1.55	1.26-1.91	<.001
Other	1.12	0.90-1.39	.31	1.17	0.92-1.50	.21	1.16	0.87-1.56	.31	1.05	0.88-1.26	.20
Race												
White	REF			REF			REF			REF		
Black	1.15	1.00-1.32	.05	1.09	0.94-1.27	.27	1.25	1.05-1.47	.01	1.18	0.98-1.43	.08
Other	1.15	1.00-1.32	.06	1.15	1.00-1.32	.05	1.07	0.89-1.29	.46	1.05	0.88-1.26	.58
Ethnicity												
Not Hispanic	REF			REF			REF			REF		
Hispanic	1.10	0.96-1.26	.17	1.00	0.87-1.14	.98	1.17	0.99-1.40	.07	1.10	0.93-1.31	.27

Central-line management requires time-intensive attention. A study by Belza et al found that caregivers spend approximately 29 hours per week providing direct medical care to children with SBS.[21] Moreover, caregivers of children with complex medical needs experience significant psychological and physical challenges,[21-24] are susceptible to financial strain,[25] and may have other children in the home requiring care. Thus, our findings may reflect the impact of these various competing demands. Future efforts should focus on identifying specific household-level factors that may be contributing to these disparities, including household size and financial situation. Further, 2.4% of patients in our cohort experienced 10 or more CLABSI hospitalizations. We recommend additional research to characterize the social needs of patients with a high burden of CLABSI hospitalizations. These patients may benefit most from interventions to prevent central line infection.

We identified racial disparities in health care use that persisted after adjustment for neighborhood income and other factors. Specifically, Black children had longer hospitalizations than White children. This builds on previous work by Harrington et al, who identified longer LOS for Black children hospitalized with common inpatient pediatric diagnoses.[26] We conceptualize race as a social construct that provides insights into the ill effects of racism on health outcomes. Although the etiology for these racial disparities in LOS remains unclear, we suspect that unmeasured social factors are contributing. The increased LOS in minoritized racial groups may be related to social barriers delaying discharge. For example, hospital discharge for children with SBS is complex and requires a concerted effort between the medical team, home parenteral nutrition provider, and caregivers that is not easy to coordinate. Hospital interventions to address barriers to discharge, such as timely coordination of caregiver teaching on antibiotic administration for children with CLABSI, may help narrow the existing racial disparities in hospital LOS.

In recent years, there have been marked changes in the practice of intestinal rehabilitation for SBS. Among these changes, we have seen the implementation of multidisciplinary care through dedicated intestinal rehabilitation centers and a wider use of ethanol-lock prophylaxis (ELP) for the prevention of CLABSIs.[2,3,27] Our study period of 2006 to 2015 falls largely outside the time period of consistent ethanol lock use in the US; therefore, the benefits of this approach to CLABSI prevention are not fully captured in this cohort. More recent developments have made ELP cost-prohibitive for many patients, with a reported cost of nearly $1000/day.[28,29] These recent barriers to ELP access could exacerbate existing disparities in CLABSI hospitalizations across socioeconomic groups. Future work should explore the impact of access to preventative measures, including ELP, nursing assistance with dressing changes, and home nursing visits on trends in CLABSI hospitalizations. Widespread access to such resources may provide a path to mitigate socioeconomic disparities in CLABSI.

Our study should be interpreted in light of several limitations. First, there is no singular ICD-9-CM code for SBS, and the PHIS does not include data on residual bowel length, a criterion that can be used to diagnose SBS. Due to these limitations, additional patients with a temporary need for parenteral nutrition may have been included in our cohort, and patients meeting criteria for SBS solely based on bowel length were omitted. However, we identified patients with SBS using the same combination of ICD-9-CM codes employed in previous studies.[12,15] The combination of ICD-9-CM codes used ensured that we included patients at high risk for morbidity—those with dependence on parenteral nutrition.[3] Second, all patients in our cohort

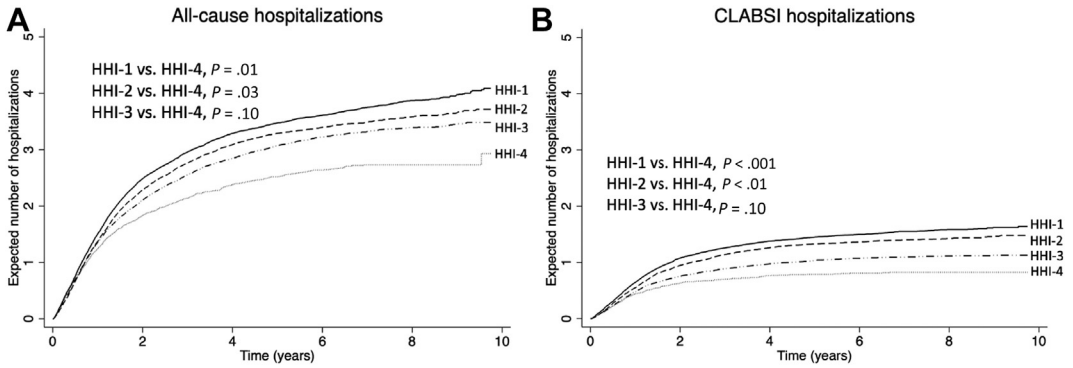

Figure 2. Univariable recurrent event analyses for cumulative expected number of all-cause and CLABSI hospitalizations by neighborhood income group. HHI-1: <$33 075; HHI-2 $33 075 to $44 099; HHI-3 $44 100 to $66 149; HHI-4 ≥$66 150.

were hospitalized at freestanding children's hospitals. This may limit generalizability to smaller, community-hospital settings. However, since PHIS includes most US centers with dedicated intestinal rehabilitation teams, we suspect that these disparities could be even greater in other hospital settings. Finally, neighborhood income was designated based on ZIP code–level data. Although ZIP codes may not be the ideal geographic unit for all research, they are relatively small geographical units and readily available in PHIS, thus enabling us to evaluate the impact of neighborhood SES on SBS outcomes.[30]

In conclusion, our analysis shows associations between neighborhood income and hospitalizations in children with SBS. Since neighborhood-level income can be a proxy for household-level resources, future research should explore both household (eg, household level SES stressors) and community-level factors, (eg, home health availability) that may contribute to increased CLABSI infections. Such data would enable intestinal rehabilitation centers to develop interventions that promote health equity. ■

Declaration of Competing Interest

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Data Statement

Data sharing statement available at www.jpeds.com.

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Further Reading

31. *[Dataset] Pediatric Health Information System, Children's Hospital Association*. Accessed September 13, 2022. https://cohort.childrenshospitals.org/cohort/WorkCanvas.aspx