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Disparities in Population-Level Socio-Economic Factors Are Associated with Disparities in Preoperative Clinical Risk Factors in Children

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Abstract. African American children are more than twice as likely as white American children to die after surgery, and have increased risk for longer hospital stays, post-surgical complications, and higher hospital costs. Prior research into disparities in pediatric surgery outcomes has not considered interactions between patient-level Clinical Risk Factors (CRFs) and population-level Social, Economic, and Environmental Factors (SEEFs) primarily due to the lack of integrated data sets. In this study, we analyze correlations between SEEFs and CRFs and correlations between CRFs and surgery outcomes. We used a dataset from a cohort of 460 surgical cases who underwent surgery at a children's hospital in Memphis, Tennessee in the United States. The analysis was conducted on 23 CRFs, 9 surgery outcomes, and 10 SEEFs and demographic variables. Our results show that population-level SEEFs are significantly associated with both patient-level CRFs and surgery outcomes. These findings may be important in the improved understanding of health disparities in pediatric surgery outcomes.

Keywords. Correlation analysis, k-means, Pediatric surgical outcome, Racial disparity, Socioeconomic factors, Social determinant of health.

1. Introduction

A disproportionate number of African Americans (AA) have a lower than average socioeconomic status. AA are two times more likely to be unemployed [1] and more likely to experience multidimensional poverty [2] than their white counterparts. As a result, 39% of AA children live in poverty (14% for white children) [3]. These children are more likely to attend high-poverty schools with higher drop-out rates [4] compared to white children. According to the American Physiological Association [5], AAs have worse overall health than that of whites [7] potentially stemming from disparities in

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Social, Economic and Environmental Factors (SEEFs) [5,6]. Racial disparities also exist in pediatric surgical outcomes. AA children are more than twice as likely to die after surgery compared with white children [8] and have significantly higher morbidity and resource utilization compared to white children [9,10]. Moreover, our previous studies suggest that racial disparities also exist at the preoperative clinical condition of children [8]. However, there is no data to date examining the direct associations between SEEFs and CRFs relevant to surgery outcomes. Therefore, the causality [11] links between population-level SEEFs and patient-level clinical risk factors (CRFs) are not well understood. Improving our understanding of associations between SEEFs and CRFs can help to reduce racial disparities in pediatric surgery outcomes. This knowledge gap may be one of the reasons for persisting racial disparities among children despite a dramatic decline in surgical mortality and morbidity of children in the United States over the past 30 years [12].

Shelby County, within Memphis, Tennessee has a large AA population (~65%) and is one of the US counties with very high rates of health disparities. Thus, there is a critical need for a better understanding of how and to what extent population-level SEEFs drives pediatric surgical outcomes in this region. In this paper, we investigate the association between population-level SEEFs and patient-level CRFs in a cohort from a children's hospital in Memphis using correlation analysis and k-means clustering over an integrated dataset containing population and patient-level data.

2. Methodology

2.1 Dataset Integration

One of the main challenges of studying the association between SEEFs and surgery outcomes is the lack of a coherent integrated data set consisting of patient-level perioperative clinical data with the related neighborhood-level social, economic and environmental data. To overcome this problem, we aligned, mapped and integrated multiple data sources with detailed information on residential and neighborhood quality, along with health-related data linked to individual surgical outcomes. The patient-level data were obtained from 460 surgical cases at a children's hospital in Memphis, TN. This subset of operations was reported to the National Surgery Quality Improvement-Pediatrics (NSQIP-Ped) between January 2014 and May 2017. We then merged the individual-level patient data for these 460 surgical cases with aggregated SEEFs data from the Memphis Property Hub (MPH) (http://caeser-midt.memphis.edu:8080/nst/) and 2016 United States Census data. Integrating the individual data with the neighborhood/ environmental data, we nested the individual-level encounter data within the zip code area of patients' residency. We limited the focus of this study to evaluate disparities in outcomes of operations on children whose parents or guardians are residents of 29 zip codes in Shelby County, Memphis (refer to Table I for details on zip code statistics).

2.2. K-Means Clustering and Correlation Analysis

The integrated dataset of 460 surgical cases consists of 23 preoperative CRFs, including do not resuscitate status, oxygen support, ventilator dependence, previous cardiac intervention, minor risk factor, severe cardiac risk factor, major cardiac risk factor, sepsis, cerebral palsy, bleeding disorder, neuromuscular disorder, hematologic disorder, systemic inflammatory response syndrome, septic shock, childhood malignancy, open wound with or without infection, inotropic support, blood transfusion within 48 hours prior to surgery, neonate, case emergency, case urgency, duration of hospital stay, and age at the time of surgery. We also had socio-economic and environmental factors such as broken window ratio, trash prevalence, mean and variance of housing quality in a neighborhood, proportion of individuals below the federal poverty level, blight prevalence, gender, race, and health insurance information at a zip code level.

We analyzed the association between percentages of AA population in a zip code with SEEFs. Focusing on the environmental determinants and CRFs influencing surgical outcomes, we compared prevalence distributions of adverse surgical outcomes in Memphis. We examined how residential disparities and other neighborhood effects can help to explain disproportionate outcomes of adverse events in surgical units among AA and whites in Memphis. We conducted k-means clustering (k=2) on population-level SEEFs to classify zip codes into two clusters. We then extended our analysis to find the correlation between SEEFs and CRFs. We also evaluated how pediatric surgery outcomes (like readmission related to principal procedures, first unplanned return to the operation room, and others mentioned in Fig.1) are correlated with the presence of preoperative CRFs.

Table 1. Descriptive statistics for zip code level aggregate data from Shelby County.

Zip code no.	No. of surgical cases	AA (%)	Female (%)	Mean age at the time of surgery in years (SD)	Mean duration of stay in hospital in days (SD)
1	28	17.03	60.71	7.84 (5.28)	7.82 (20.61)
2	12	40.59	41.67	4.97 (5.82)	12.25 (22.71)
3	17	27.34	35.29	7.12 (6.39)	5.47 (4.26)
4	2	30.16	0.00	2.87 (1.76)	8.00 (4.00)
5	3	25.52	100.00	6.34 (7.34)	14.67 (17.25)
6	4	81.50	75.00	1.55 (0.21)	8.25 (7.69)
7	14	86.88	50.00	5.67 (6.00)	5.29 (4.65)
8	7	81.70	28.57	2.82 (3.90)	6.43 (5.26)
9	12	64.98	58.33	5.79 (5.95)	9.00 (12.31)
10	34	95.52	47.06	7.11 (6.97)	13.65 (19.59)
11	22	53.26	45.45	8.80 (6.82)	14.27 (36.49)
12	5	56.66	60.00	7.18 (4.57)	8.00 (7.16)
13	19	94.50	52.63	2.76 (3.90)	18.11 (25.96)
14	27	85.35	55.56	3.50 (5.06)	26.89 (29.84)
15	15	95.36	53.33	6.55 (6.55)	20.33 (27.51)
16	12	11.87	16.67	2.58 (3.30)	27.75 (48.33)
17	24	78.45	50.00	4.95 (6.09)	15.79 (35.57)
18	9	36.58	11.11	11.64 (5.35)	8.00 (10.41)
19	8	4.82	37.50	3.95 (5.39)	17.13 (24.59)
20	17	21.19	35.29	5.54 (4.56)	5.82 (5.69)
21	23	80.14	43.48	7.09 (5.63)	8.57 (12.55)
22	3	80.45	66.67	9.83 (6.84)	18.33 (19.57)
23	31	81.57	48.39	7.62 (6.40)	8.65 (20.81)
24	28	73.04	32.14	6.05 (5.73)	23.71 (67.72)
25	18	19.95	50.00	4.80 (4.22)	7.28 (7.94)
26	17	44.74	64.71	5.53 (5.82)	9.71 (17.49)
27	20	24.96	40.00	5.58 (5.35)	6.30 (10.33)
28	15	5.56	40.00	9.58 (6.78)	3.60 (2.63)
29	14	82.49	50.00	10.94 (7.06)	4.14 (3.09)

3. Results

The proportion of AA population in the two zip code clusters was compared with *t*-test which rejected the null hypothesis ($p<0.01$) implying that the AA population percentage in Cluster 1 zip codes is significantly smaller than in Cluster 2 zip codes. The mean difference with 95% confidence interval (CI) of the AA population percentage between Cluster 2 and 1 was found to be 43.09 [26.43-59.75]. Table 2 reports the average SEEFs 95% CI statistics for the two clusters. We also found significant differences with Mann-Whitney U-test used due to non-normality of data ($p<0.1$) between Cluster 1 and 2 in terms of CRFs, such as ventilator dependence, oxygen support, minor cardiac risk factor, and neonate and surgical outcomes, such as unplanned intubation, first unplanned return to the operation room, and readmission related to principal procedures. Fig. 1 and Fig. 2 shows the plot of representative SEEFs and CRFs in each cluster, respectively.

Further, we evaluated the significance of the correlation between SEEF- CRF and between CRF-Surgery outcomes using a two-tailed *t*-test. Fig. 3 shows the Pearson correlation coefficients between the variables that were found to be statistically significant at either $\alpha=0.01$ or 0.05. Understanding the pathways through which the neighborhood social conditions and built environments influence geo-social and health disparities are crucial. Detailed neighborhood-level data along with other data sets enable us to reveal the pathways of social inequalities to health disparities. Our preliminary results on identifying correlations among SEEF, CRF, and surgical outcomes suggest further investigation of underlying causality patterns. Such knowledge can facilitate, design, implementation, and evaluation of targeted interventions to address disparities in pediatric surgery outcome.

Table 2. SEEF statistics (mean [95 %CI]) obtained from each cluster.

SEEF	Cluster 1	Cluster 2
Blight prevalence	2.3 [3.3 1.5]	9.5 [11.9 7.2]
Broken Window ratio	0.1 [0.2 0]	1.1 [1.5 0.8]
Trash presence	0.05 [0.1 0]	0.6 [0.9 0.3]
Neighborhood inequality	0.5 [0.6 0.5]	0.8 [1 0.8]
Individual below poverty	10.0 [13.2 6.9]	37.2[41.5 32.8]
Female %	42.2 [55 29.4]	50.6 [56.8 44.3]
AA %	32.3 [44.8 19.7]	75.4 [85.3 65.4]
Health Insurance %	37.5 [47.4 27.6]	74.8 [92.2 57.5]

Figure 1. Scatter plot of three representative SEEFs.

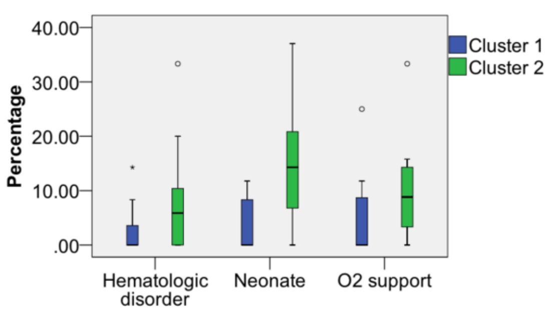

Figure 2. Box plot of three representative CRFs in two clusters. Note that AA population is predominant in Cluster 2 zip codes.

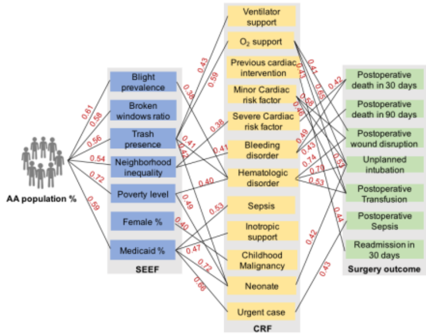

Figure 3. Correlation analysis depicting associations between AA population-SEEF, SEEF-CRF, and CRF-pediatric surgery outcome. The magnitude of the correlation is mentioned along with the connection link.

4. Conclusions

Our results on 460 surgical cases show that there are significant correlations between SEEFs, preoperative CRFs, and surgical outcomes. Although it is difficult to conclude causality due to the small and possibly biased sample size, our results suggest that there are important associations between population and patient-level risk factors for adverse surgical outcomes. In addition, our results indicate that zip codes with larger AA population have significantly poorer socioeconomic and environmental indicators. Children from high-risk neighborhoods have a higher rate of preoperative CRFs and a higher rate of adverse events after surgery compared to children from the lower-risk zip codes that also have a lower proportion of AA. As a future work, we want to discover causality patterns between SEEFs and CRFs by performing predictive modeling on a dataset from a larger cohort by utilizing advanced statistical modeling methods.

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