ORIGINAL RESEARCH

Spatial Distribution of Congenital Birth Anomaly Costs: Environmental and Geographic Exposure Associations in Los Angeles County

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Introduction

Associations Between Environmental Toxins and Poor Birth Outcomes - Exposure to environmental hazards can correlate with many different childhood and neonatal health risks, and congenital anomalies.[1-4] According to the CDC, approximately 60% of birth defects are of unknown etiology and potentially explained by complex interactions between genetic and environmental factors.[5] Congenital anomalies, defined as birth defects noted at the time of delivery or shortly thereafter, are a specific category of birth outcomes that are multifaceted in origin.

Congenital anomalies occur in approximately 3% of all live births.[6] Two hundred ninety-five thousand newborns with a birth defect die within the first 28 days of life annually worldwide.[7] A 2013 Morbidity and Mortality Weekly Review report, reported that hospitalizations for birth defects totaled as much as 5.2% of all hospital costs, up to $22.9 billion per year.[6] This was more than twice as expensive as admissions for all other conditions. However, congenital anomalies are extremely heterogeneous and their hospitalization costs can vary widely. Cardiac and chromosomal anomalies, for example, tend to be the costliest anomalies.[6,8] In contrast, pyloric stenosis, cleft palate without cleft lip, and cleft lip with or without cleft palate, are the least costly.[8]

In large, diverse regions such as Los Angeles County, the burden of exposure to toxins often falls disproportionately upon people of color and those who are low-income, many live near hazardous facilities, such as waste sites and industrial parks, located primarily in low-income communities.[9,10] Hazardous waste exposure, has been linked to anomalies of the urogenital, connective and musculoskeletal systems.[11] In Los Angeles County, toxic spots include East Los Angeles, Southeast Los Angeles, the San Fernando Valley, and the Ports of Los Angeles and Long Beach.[12] Prior research found pregnant women living in "hot spot" neighborhoods have an increased risk for low birth weight and preterm birth.[13,14] The combination of hazardous exposure and psycho-social stress in these environments can "…amplify these health disparities by enhancing community susceptibility to the effects of toxic substances".[12]

Although exposure to certain environmental pollutants is regulated, toxins such as lead have not been fully eradicated and remain in a variety of products and older houses.[15,16] For example, in Los Angeles County, lead-based paints have been banned for residential use since 1978, yet 23.0% of adults reported that their home or apartment built before 1978 had peeling or chipping paint, leaving them and their families at risk for lead exposure.[17,18] The Pew Research Center reported if lead exposure was prevented among all children born in 2018, the potential benefits could reach $84 billion.[19] Autism is another example of poor health outcomes in children linked to environmental exposure. In California, an association was found between air pollutants and increased risk of autism in children. Mothers living near freeways were more likely to have their child be diagnosed with autism.[20,21] This association is increased for lower socioeconomic families, who are more likely to live near freeways or in areas with higher traffic-related air pollutants.[21-23]

Applications of Geospatial Analysis - Spatial patterns of congenital anomalies differ by region in Los Angeles County and are not randomly distributed.[24] The pattern of congenital anomaly distribution, however, does not appear to correlate with race, ethnicity, health care access, or income. Using spatial statistics, hot spot analysis compares local areas against the larger region to identify areas where high (hot spots) or low (cold spots) values are clustered together. Within Los Angeles County, the Antelope Valley and San Gabriel Foothills are two hot spots that were identified with disproportionately higher incidence rates of congenital anomalies. Results found increased risk of congenital anomalies was more closely associated with environmental conditions present in these hot spots. Possible explanations included differing air and water quality, as well as air pollutants that impact ozone levels. Hot spot areas had elevated ozone levels, which have been previously linked to birth anomalies.[24] Increased exposure to air pollution one month before conception was the time period when the risk for congenital anomalies was the highest.

To better guide health and environmental policy, the objective of this study is to determine if the fiscal impacts of congenital anomalies also differ by spatial region in Los Angeles County. Given that the provision of health care is increasingly organized regionally, if the impact of toxins varies by geography, it may disproportionately impact health care delivery in different communities.

Materials & Methods

This study reviewed birth records from the Vital Statistics Birth Master File for Los Angeles County for the years 2006-2010. This database contains detailed demographic and medical data associated with every newborn infant. Of most importance to this study were the maternal home address and presence of genetic and non-genetic birth anomalies. To control for confounding, the only birth records used were those from non-smoking mothers aged 15-35 years old.

The cost for each birth anomaly type was assigned from a prior study that estimated a total cost per anomaly, including the facility fees charged by the hospitals as well as the cost of physician services.[6] The median cost was coded to each birth defect as recorded in the Vital Statistics Birth Master File. [Table 1]

Birth records were geocoded to maternal home address for all those birth records in the subgroup containing a complete street address and zip code. Total costs per anomaly were calculated by aggregating the point data up to US Census Bureau Public Use Microareas (PUMAs). Within Los Angeles County, there are 69 PUMAs with an average area of 58 square miles and an average population of 142,299 according to the 2010 census. The larger PUMA geography was chosen as a unit analysis because even in a highly populated area like Los Angeles County, the number of birth anomalies is small.

Hot spot analysis was then conducted using ArcGIS 10.5 software on the total costs per PUMA to identify areas of spatial autocorrelation. Spatial autocorrelation is the measure of how well nearby regions are related to one another and is used to identify clusters of spatial data with similar values in hot spot analysis. The weight matrix for this analysis was defined by the polygon contiguity edges and corner rule. This parameter constrains the calculation of each polygon's Getis-Ord Gi* statistic to only its first-order neighbors, with all the outlying polygons having no influence. An additional cluster analysis was also conducted to corroborate the hot spot analysis result. The cluster analysis tool within ArcGIS 10.5 calculates Anselin's Local Moran's I as a measure of spatial autocorrelation for each feature and its associated neighborhood. The UCLA Institutional Review Board approved the study IRB#13-000106.

Results

For the five-year birth record sample, 462 anomalies were identified among 436,218 births (0.10%) in Los Angeles County. Seventeen birth anomaly types were found with gastroschisis coded as the most expensive ($46,134) and anencephaly as the least expensive ($791) per case. The total additional health care costs for all birth anomalies in Los Angeles County were calculated to be $6,526,698. The mean cost by PUMA was $94,589 with a large standard deviation of $81,162. The PUMAs with the highest costs were both located in the Antelope Valley: Lancaster City ($438,303) and Palmdale City ($437,529). There were two PUMAs with no birth anomalies found: Redondo Beach, Manhattan Beach & Hermosa Beach Cities ($0) and Burbank City ($0). [Figure 1]

The hot spot analysis of the median costs found a hot spot (99% confidence level) in the northern half of Los Angeles County. This hot spot was composed of the two PUMAs in the Antelope Valley (Lancaster City and Palmdale City), as well as the large, mostly unincorporated Castaic PUMA. The North Central/ Granada Hills & Sylmar PUMA was also included at the 95% confidence level. Geographically, these areas north of the San Gabriel Mountains are largely a part of an elevated high desert plateau within the western tip of the Mojave Desert. Additionally, while Lancaster and Palmdale are significant cities within Los Angeles County, the population density in this region is less than the areas to the south within the Los Angeles basin. Cold spots were found in the western portions of the county including most prominently the Central/Pacific Palisades and Central/Hancock Park & Mid-Wilshire PUMAs (99% confidence level). These areas are more densely populated urban areas than the identified hot spot regions.

The cluster analysis of median costs found grouping of high cost areas (high-high cluster) in the same three PUMAs identified in the hot-spot analysis. A grouping of low-cost areas (low-low clusters) were also identified in the same region as the 95% confidence level cold spots. Additionally, two outlier PUMAs where a high cost area was adjacent to a low-cost area (high-low outlier) were identified: Central/Pacific Palisades and Gardena, Lawndale Cities & West Athens.

Race/ethnicity was not a significant confounder of birth anomaly cost. The median cost per birth anomaly was similar across the five race/ethnicity categories examined: Asian, Black, Hispanic, Other, and White. The lowest median cost per birth anomaly was found for the Asian category ($12,655) and the highest was found in the "Other" category ($17,941). Additionally, median household income was not identified as a significant confounder (r-squared = 0.0094).

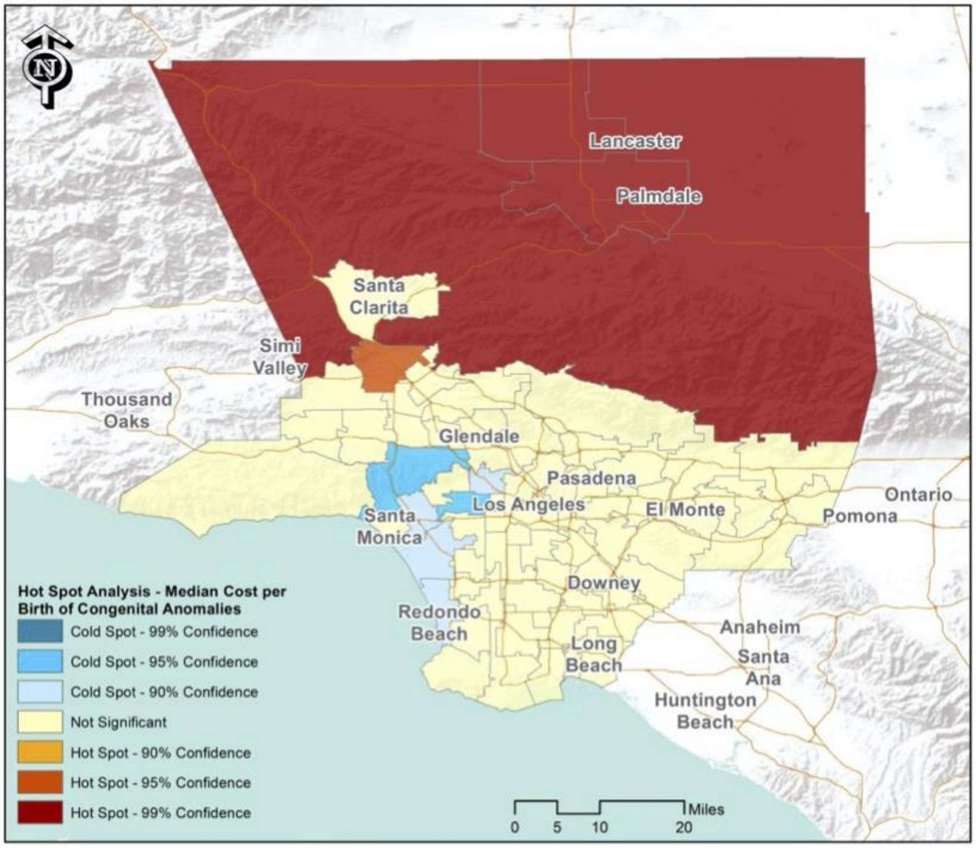
Tables and Figures

Birth Anomaly	Median Cost[2]
Anencephaly	$ 791
Meningomyelocele/Spina bifida	$ 10,235
Cyanotic Congenital Heart Disease	$ 14,552
Congenital Diaphragmatic Hernia	$ 18,605
Omphalocele	$ 17,415
Gastroschisis	$ 46,134
Limb Reduction Defect	$ 11,128
Cleft Palate Alone	$ 9,162
Cleft Lip Alone	$ 4,530
Cleft Palate with Cleft Lip	$ 9,854
Down's Syndrome	$ 8,922
Suspected Chromosomal Disorder	$ 9,067
Hypospadias	$ 2,477
Aortic Stenosis	$ 27,483
Pulmonary Stenosis	$ 23,289
Atresia	$ 9,737
Additional and Unspecified Congenital Anomaly	$ 8,366

Table 1 – Median cost of birth anomaly types

Race/Ethnicity	Births	Birth Anomalies	Median Cost Total	Median Cost per Birth	Median Cost per Birth Anomaly
Asian	33,701	28	$ 354,331	$ 10.51	$ 12,655
Black	24,385	18	$ 287,783	$ 11.80	$ 15,988
Hispanic	316,592	338	$ 4,715,094	$ 14.89	$ 13,950
Other	13,239	13	$ 233,227	$ 17.62	$ 17,941
White	48,301	65	$ 936,263	$ 19.38	$ 14,404

Table 2 – Birth anomaly costs by race/ethnicity



	Birth Anomaly Costs	Birth Anomaly Costs per Birth
Los Angeles County	$6,526,698	$14.96
Hot Spots	$1,188,277	$45.19
Castaic	$149,941	$35.83
Lancaster City	$438,303	$53.18
Palmdale City	$437,529	$53.53
LA City (North Central/Granada Hills & Sylmar)	$162,504	$28.54
Not Significant: Neither Hot nor Cold Spot	$5,020,319	$13.25
Cold Spots	$318,102	$10.26
LA City (Central/Hancock Park & Mid-Wilshire)	$47,568	$7.81
LA City (Central/Pacific Palisades)	$109,270	$28.25
LA City (East Central/Hollywood)	$42,444	$7.06
LA City (Southwest/Marina del Rey & Westchester) & Culver City	$91,438	$17.63
LA City (West Central/Westwood & West Los Angeles)	$27,382	$4.67
Redondo Beach, Manhattan Beach & Hermosa Beach Cities	$0	$0

Figure 1 – Hot spot analysis of median cost per birth with congenital anomalies

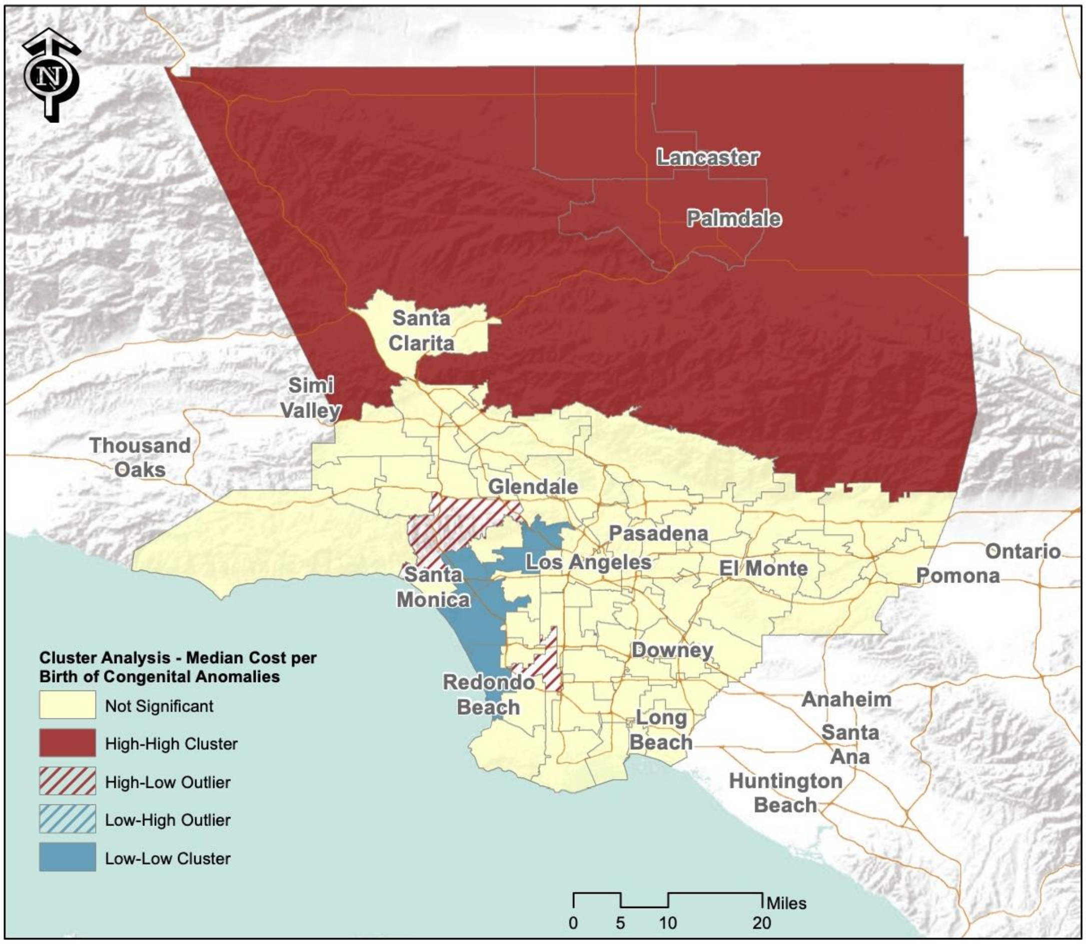


Figure 2 – Cluster analysis of median cost per birth with congenital anomalies

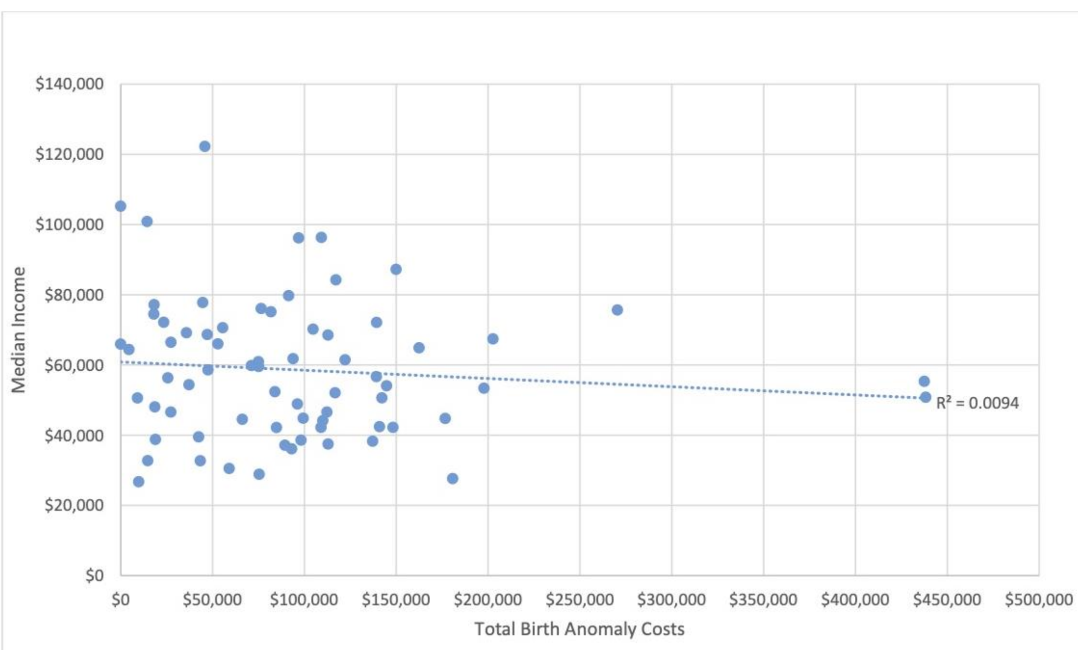


Figure 3 – Median income scatter plot

Discussion

The cost of congenital anomalies varies by geographical location. Costs are not always limited to medical expenses. Unlike some poor birth outcomes, anomalies are not associated with race and income. If anything, more frequent and costly anomalies are found in PUMAs where average income and education is higher than in other areas of Los Angeles County.

The variance of costs of anomalies in certain regions provides further guidance for ongoing studies of the relationship between geography and risk of congenital abnormalities. Well-recognized risk factors for congenital anomalies typically include age, health status, and genetics.[7,25] Environmental exposure during the preconception period should also be addressed in both preconception counseling and in prenatal care. Well-accepted impacts of poor air quality include asthma and pulmonary disease[26]; birth anomalies need to be recognized as well.[27] Despite the links between exposure to environmental hazards and congenital anomalies, less than 20% of physicians ask their pregnant patients about exposure to environmental hazards and chemicals.[28] In order to raise this percentage, more physicians need to be educated about reproductive harm linked to environmental exposures and the importance of asking about exposure during prenatal visits.[29,30]

Conclusion

The possible lifelong costs of congenital anomalies for special education and accommodations, physical and occupational therapy, mental health services, and rehabilitation can exceed multiple millions of dollars per affected individual. Additionally, subsidized housing and disability payments over the course of their life may be required. This places burdens on individuals, families, and society at large.

Linking health care cost and the incidence of congenital anomalies on a regional level is essential. Examination of these interconnections uses an outcome measure and cost analysis. This will speak to policy and public health stakeholders, as well as the private sector. Advocating for expansions in policy recommendations, regulatory compliance, and public health interventions paves the way for reducing congenital anomalies associated with environmental exposure before, during, and beyond pregnancy.

Limitations

This study has three major limitations.

First, the incidence of congenital anomalies in the study period is low, approximately 1%, with several PUMAs reporting anomalies in the single digits. Analyzing the incidence of anomalies over a longer period and/or larger region would add more power and make the data more generalizable.

Secondly, the current study assigned the cost for each anomaly based on nationwide median costs. This may not accurately reflect the actual health care cost of individual cases in this analysis. Health care costs in Los Angeles County, an urban hub, are likely higher than in other areas. Considering this study as preliminary, may power future research into the associations between the environment and the cost of birth defects on a much larger scale. Additionally, although biologic plausibility between air quality, environment and anomalies is based on prior work, associations do not indicate causality.

Finally, despite Los Angeles County being a region with exceptionally diverse geographic environments, our study focused primarily on urban environments, which account for the majority of the study area. As a result, the healthcare access issues found in rural environments were not included in our examination of birth anomaly costs. These limitations provide grounds for future research.

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