Identifying Geographic Clusters Associated with Gastroenteritis in Kingston, Jamaica

Presentation

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Abstract
Geographic Information System (GIS) has been increasingly recognized as an important tool for mapping and analyzing disease patterns. In this paper, we use easily accessible GIS tools to identify places in the Kingston Metropolitan Area that have experienced high levels of gastroenteritis cases. In addition, data obtained from the national census is used to estimate correlations between gastroenteritis counts in different communities and predictor variables.

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Introduction

Outbreaks of gastroenteritis contribute significantly to morbidity and mortality in developing countries, including those in the Caribbean and Latin America. In Jamaica, childhood gastroenteritis is common, with approximately 18,195 cases reported in 2001 and 22,230 cases reported in 2002 (Ministry of Health, Jamaica, 2003). Most of the cases have been linked to the rotavirus, with transmission occurring via water-borne routes. Rotavirus cases occur mostly among children aged less than 3 years and usually peak in the cooler months of the year (Figure 1). The peak in the cooler months is similar to the pattern in northern climates. In May 2003, a large outbreak of severe acute gastroenteritis (AGE) occurred in Jamaica and this was also ascribed to the rotavirus, despite its occurrence during the warm summer months and the fact that large numbers of children over 3 years old were affected (Figure 1; Ashley et al, 2003). Researchers have hypothesized that heavy rainfalls that occurred in late May might have flooded latrines in crowded urban areas, causing fecal contamination of water sources (Ashley et al, 2003).

Controlling outbreaks of gastroenteritis depends on identifying and removing the source of contamination. This paper describes how Geographic Information System (GIS) was used to help identify clusters in gastroenteritis cases treated at the Kingston Public Hospital and Bustamante Children Hospital, Jamaica, in 2002. Regression modeling was then used to test the relationship between variations in gastroenteritis cases in the Kingston Metropolitan Area and a number of social and environmental risk factors.

Figure 1. Number of acute gastroenteritis cases in persons less than 5 years and persons 5 years and older, by month, Jan. Dec 2002.
Data Sources

Gastroenteritis data were obtained from the Ministry of Health, Jamaica for the period January – December 2003. The data do not represent cases for the entire Kingston Metropolitan Area. Rather, they represent cases treated at the Kingston Public Hospital (KPH) and the Bustamante Children Hospital, which pertained to the Kingston Metropolitan Area. The KPH treats adult patients affected with gastroenteritis, while the Bustamante Hospital caters to children cases. In all, a total of 2,245 gastroenteritis cases were analyzed for this study.

A digital community map of the KMA was obtained from the Ministry of Health GIS unit. This map contained a total of 108 communities or Special Areas. The Special Areas are comprised of combinations of enumeration districts, a characteristic which make them useful units for public health mapping, as disease rates can be easily calculated for the communities. Socio-economic data from the 2002 census were obtained and joined to the attribute table of the base map. These data included variables such as the total number of dwellings with access to pure water, access to varying types of toilet facilities, number of people with different educational levels, total population in different communities, etc.
These variables allowed tests to be made to determine whether associations existed between socio-economic conditions in the KMA and incidences of gastroenteritis.

Methods

Ascertaining Geographic Clusters in the Dataset

In order to locate areas that experienced high levels of gastroenteritis cases in 2002, the addresses of the 2,245 gastroenteritis patients were geocoded using the GIS software ArcView 3.3. The resultant point pattern is shown in Figure 2.

Figure 2

A cursory examination of the point pattern revealed that there is a definite concentration of gastroenteritis cases in the south and western parts of the city. Such a concentration meant that there was little value in carrying out a global test for clustering against the complete spatial randomness of a Poisson distribution. The analysis thus began by utilizing kernel density analysis to highlight first order effects in the spatial point pattern. First order effects refer to variations in the intensity of points across a study area. Usually, these variations are caused by some process operating at different locations. First order effects are important in the context of this study as it helps in the identification
of places in the KMA where some environmental process is at work giving rise to the elevated levels of gastro-enteritis cases.

In order to create the kernel density map, the ArcView utility was overlaid with a fine grid over the study area and then each grid cell was visited with a roving window of fixed bandwidth \( \tau \) and kernel \( k \). The kernel is a function that weighs each point within the bandwidth based on its distance from the point at which the intensity is being estimated. An average is then made of the number of events within the window. Kernel estimation has the useful advantage of portraying clusters that do not adhere to the boundaries of administrative units, thus it avoids the limitation of choropleth maps which gives the impression that disease clusters are distributed homogeneously within spatial units and that their intensity ends abruptly at the boundaries of these units. Also, by superimposing streets maps on the clusters, a high level of geographic targeting of intervention activities can be achieved, right down to the level of particular street segments. Kernel density was estimated with the Spatial Analyst of ArcView 3.3.

Despite its usefulness as an exploratory analytical tool, a kernel density map does not provide information on whether gastroenteritis rates in neighboring communities are correlated with each other, and whether this correlation is significant. Knowledge of this correlation is important in a viral gastroenteritis study because the disease is also spread through human-to-human transmissions; hence, when identifying clusters, there is frequently a need to distinguish between clusters caused by environmental factors operating at a particular location, e.g., poor sanitation, and clusters caused by locations being in close proximity to neighboring areas where infection is high. The latter effect is referred to as second-order or interaction effects and is estimated using spatial autocorrelation techniques.

In order to identify areas where clusters are due to pronounced second order effects, the local \( G^* \) statistic was used (Getis and Ord, 1992). The local \( G^* \) statistic detects spatial autocorrelation in a dataset and highlights clusters of hot or cold spots in the study area. It is calculated by passing a moving window across the data and examining dependence within the neighboring region of the polygon on which the window is centered. The
specification for the window can vary, using contiguity or distance at some spatial lag from the considered point or zone. The Space Time Intelligence System (STIS) software developed by Biomedware was used to calculate the local G* statistic. Since the statistic is based on polygon level data, the total number of geocoded points contained in each Special Area in the KMA was calculated and transformed into gastroenteritis rates. The STIS software calculated local G* statistic for each polygon based on spatial weights for the nearest five neighbors of each polygon. The local G* statistic is actually a Z-value. High positive Z-values indicate the possibility of a local cluster of high values; very low Z-values indicate a cluster of low values.

Analysis of Risk Factors
Most gastroenteritis cases in Jamaica are ascribed to the rotavirus, which is transmitted via the fecal-oral route. The virus spreads easily under conditions of poor hygiene and overcrowding. In order to measure aspects of hygiene in communities in the Kingston Metropolitan Area, the following census-based variables were used: Households utilizing pit latrines; Households with access to flush toilet or water closets; Households with access to public piped water, Households with access to private piped water, Households with Access to private standpipes, Households depending on springs and rivers for Water.

A multiple regression analysis was used to test the extent to which the gastroenteritis rates in the different Special Areas of the Kingston Metropolitan Area (KMA) were associated with the rates for the various gastroenteritis risk factors. A step-wise regression was performed using SPSS.

Results

Clustering
Figure 3 shows the density map that was created to identify locations in the KMA where gastroenteritis clusters were due to first order effects. In all, six hotspots or clusters were identified. Clusters were arbitrarily defined as areas where density levels matched any of the three highest classes in the legend generated by ArcView for the density map. A notable aspect of these hot spots is that they are irregularly shaped, adhering more to the
contours caused by varying density of gastroenteritis cases, rather than being restricted by the geographies of community boundaries. In the majority of cases, the areal extent of clusters did not occupy entire communities. This characteristic is important because it highlights the well-known fact that rarely is an entire community affected at the same rate by a disease occurrence.

Among the six clusters identified, three had very high rates. The cluster, with the highest rate was Allman Town with an average rate of 12.9/1000. The cluster with the next highest rate was centered on the boundaries of Denham Town/West Downtown and Hannah Town/Craig Town. This cluster had an average gastroenteritis rate of 7.2/1000. The third most intense cluster was centered on the borders of Whitfield Town/Arnett Gardens and Kencot, with most of it concentrated in Whitfield Town. The average gastroenteritis rate for this area was 6.75/1000. The other three clusters were centered East Downtown, Jonestown and the boundaries of Passmore Town/Franklyn Town and Newton Square.

Figure 3. Clusters Identified Using Kernel Density Mapping
Figure 4 shows the result of the local G* statistic test. A total of seven polygons were identified as core areas where there is statistically significant clustering due to spatial interaction or second order effects. In other words, these are areas where the high rate of gastroenteritis in one special area is related to the high rates of gastroenteritis in surrounding or nearby communities. The communities included in this cluster are East Downtown, Southside, Central Downtown, Campbell Town, Allman Town, Hannah Town/Craig Town and Kingston Gardens. It should be noted that the local G* statistic identifies the core of the areas that comprise the cluster but not the entire cluster. This means some of the polygons surrounding the highlighted core polygons also have high rates of gastroenteritis.

There is considerable overlap in the clusters on the two maps. This is not an unexpected result as first order and second order effects can occur in the same general area and in such cases it is often impossible to say whether the clustering is due to environmental or
interaction effects. By combining the areas identified by the two maps, one can identify a general area that constitutes elevated levels of gastroenteritis rates.

**Figure 4. Clusters Identified by the Local G* Statistic**

![Cluster Map](image)

**Regression**

The risk factors that were hypothesized to explain the spatial variation of gastroenteritis in the KMA were all statistically insignificant, except for WATER CLOSETS ($p = .002$) and PUBLIC STANDPIPES ($p = 0.02$). The change in $R^2$ associated with water closets was 62%, suggesting that a large amount of the variation in the gastroenteritis events can be explained by this single variable. However, the relationship is direct suggesting that areas that have large amount of water closets are also the same areas that have high rates of gastroenteritis. The change in $R^2$ associated with PUBLIC STANDPIPES was just 3.4%, so water closets were by far the more important risk factor.
Discussion
Water closets or flush toilets are toilets that dispose human waste products by using water to sweep them away down a drainpipe. The water is also used as a hygienic barrier between the drainpipe and the user. Water closets are common throughout the Kingston Metropolitan Area. Analysis of the spatial pattern of households with access to water closet data in the Kingston Metropolitan Area reveal show that these facilities are widely present in the downtown areas where most of the gastroenteritis clusters occur. In fact their density is higher in downtown areas than elsewhere in the KMA. This reflect this the underlying population distribution in the KMA.

No data is available on the physical condition of the water closets in the downtown areas. However, the communities that contain the gastroenteritis clusters are known to be low income areas where the quality of infrastructure is frequently poor. Further study needs to be done to ascertain the precise conditions of water closets in these areas as well as the disposal lines, but it is believed that many of these facilities may be well below the required level of maintenance, thereby putting people at risk to gastroenteritis. For example, septic tanks that are not properly maintained can overflow, polluting surface drains and contaminating backyards where people frequent. Rainy weather worsens the problem as during rainstorms, water runs over the ground, picks up faeces and contaminates water sources.

Conclusion
The 2002 gastroenteritis data for the Kingston Metropolitan Area that was used in this study allowed the identification of gastroenteritis clusters. The GIS proved to be a useful tool for this task. The available data suggested that gastroenteritis occurrences in the study area were strongly correlated with water closets. While water closet usage in areas of gastroenteritis clusters is high, further study is needed to ascertain the physical conditions of these facilities, as it is hypothesized that the poor quality of these facilities in the downtown areas where the clusters proliferate, may be responsible for gastroenteritis outbreaks.
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