MONITORING DISEASE DIFFUSION WITHIN AN AUTOMATED MAPPING FRAMEWORK

Gerald F. Pyle
Department of Urban Studies
The University of Akron
and
Jack J. Utano
Department of Geography
The University of Akron

Introduction

During the early summer of 1977, a severe outbreak of Hepatitis "A" (HAV)[1] within the city of Akron and environs proved to be yet another example of how this disease can flare up and diffuse within a community. The purpose of this study is to demonstrate one method by which the spread of Hepatitis A can be monitored utilizing an operational DIME/ADMATCH system linked to automated cartographic techniques. In addition, the hypothesis that knowledge of patterns of spatial and temporal diffusion of Hepatitis A within the study area over several epidemiological cycles can be used to estimate locations of future outbreaks is examined.

Cycles of Hepatitis A Within Akron

Data were collected from Akron Health Department records for all reported cases of Hepatitis A for the time period July 1, 1969 to May 15, 1978. Given major advances in seriologic testing during this time span and known under-reporting due to the nature of the disease, it is assumed that: [1] Information from recent years is more reliable; and [2] Reporting during the outbreak period is probably more accurate than some of the earlier information. The cyclical nature of Hepatitis A

reporting within Akron over the time period is shown within Figure 1, with the horizontal scale indicating date of onset of symptoms. Considering a long incubation period of from two to six weeks with an average of approximately twenty-five to thirty days, six cycles have been determined on the basis of Hepatitis A activity during quarters that when aggregated form peaks and troughs irrespective of calendar years.

Since each of the case records included residential addresses, it was possible to utilize the Akron SMSA DIME File and match the cases for each cycle to census tracts and blocks. Within each cycle the information was further subdivided into quartiles of distributions. The quartiles, theoretically utilized to indicate infusion, inflection, saturation, and waning phases, were then mapped utilizing the SYMAP contour option.[2] It was then possible to develop elementary diffusion maps for each of the cycles. Generalized "clinical fronts" for Hepatitis A diffusion within Akron were identified in a fashion similar to that accomplished in earlier studies within Australia by Brownlea.[3] The pattern contained within Figure 2 shows the hypothesized diffusion pattern for the 1977-78 or outbreak cycle. The heavy areas indicate reporting during the twenty-fifth percentile, or infusion stage, and the dotted areas indicate increased reporting during the inflection stage (fiftieth percentile). While this kind of mapping derived from SYMAP procedures provides some indication of early outbreaks and movement within the city, similar surfaces developed for the other five cycles indicate that early outbreaks did not always occur in the same parts of the city. Two analyses of variance were done for each of the cycles, one with drainage categories for parts of the city and the other with housing quality. While results normally showed moderate levels of significance, there were no strong statistical associations. However, this finding at least corroborates results from other studies indicating a higher probability of hepatitis outbreaks in parts of cities where conditions can become unhygienic for one reason or another.[4]

Whether the disease was spread via the oral-fecal route or through contaminated food or water is extremely difficult to determine without actually accomplishing individual scale epidemiological investigations. Since the purpose of this study is to examine whether or not computer mapping can help monitor the generalized diffu-

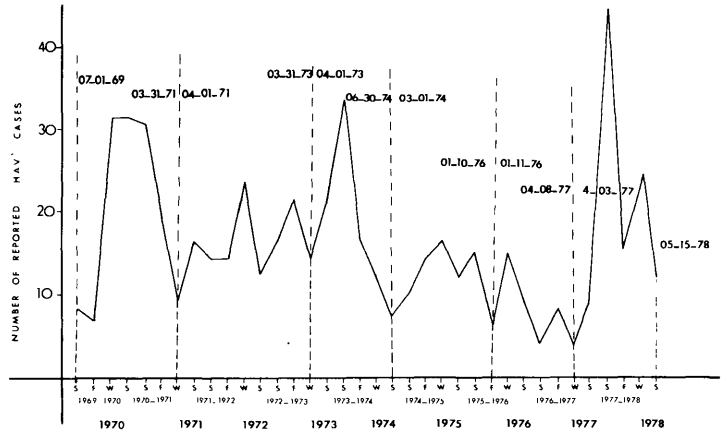

Figure 1. Reporting of Viral Hepatitis, presumably mostly "Type A", or HAV in Akron for approximately six cycles.

Figure 2. Pathways and temporal "clinical fronts" of possible HAV diffusion during the 1977-78 period. The black areas contained the earliest reporting.

sion of Hepatitis A, the concern is with broader patterns of movement within the city. One statement that can be made when examining the various diffusion maps for each cycle is that there appears to be a general tendency for earlier reporting in parts of the city that had higher levels of late reporting during the previous cycles. In order to test the latter contention, additional mapping and statistical testing were accomplished.

A Trend Surface Analysis

Assuming that there were sufficient regularities of diffusion within the city during each of the five cycles preceding the outbreak, reported cases for each percentile during each year were summed and polynomial trend surfaces were developed for the various time periods to assist in explaining the diffusion within the outbreak period. Fourth degree surfaces appear to be the most reasonable "fits" for each percentile. Table 1 contains information indicating the amount of variance explained by each of the four surfaces by percentiles. It is interesting to note that variance levels generally decreased from the twenty-fifth to the hundredth percentile for most of the polynomial surfaces with the fourth degree twenty-fifth percentile map explaining most of the variance.

An additional computer mapping program was utilized to examine the residuals from each of the diffusion surfaces. The residuals were processed through SYMAP to generate a residual surface lattice for the city. This surface, expressed in matrix form, was then processed through GRIDSHADE, a computer program designed to generate a variety of "shaded maps" from a set of raster-organized data.[5] These residual maps are contained within Figure 3. The residual surfaces depicted within Figure 3 give some idea as to where there were more or less cases than would be expected within each of the four phases during the first five cycles and might be considered generalized indicators of what to expect during the next Hepatitis A cycle.

For purposes of testing this contention, the same procedure was utilized to examine the within-cycle phases for the outbreak period. Table 2 contains the coefficients of determination for each of the trend surfaces developed through the fourth degree for infusion, in-

TABLE 1

Explanation of Variation of Hepatitis "A"
Diffusion Surfaces for First Five Cycles

	Infusion 25 P.	Inflection 50 P.	Saturation 75 P.	Waning 100 P.
First Degree	.2851	.1993	.0768	.0373
Second Degree	.3299	.2471	.1370	.0950
Third Degree	.3732	.2805	.1826	.1611
Fourth Degree	.3954	.3109	.2100	.2199

TABLE 2

Explanation of Variation of Hepatitis "A"
Diffusion Surfaces for Outbreak Period

	Infusion 25 P.	Inflection 50 P.	Saturation 75 P.	Waning 100 P.
First Degree	.1832	.1823	.1043	.1253
Second Degree	.3217	.3941	.2838	.2786
Third Degree	.4355	.4521	.4191	.3752
Fourth Degree	.4958	.4714	.4665	.4513

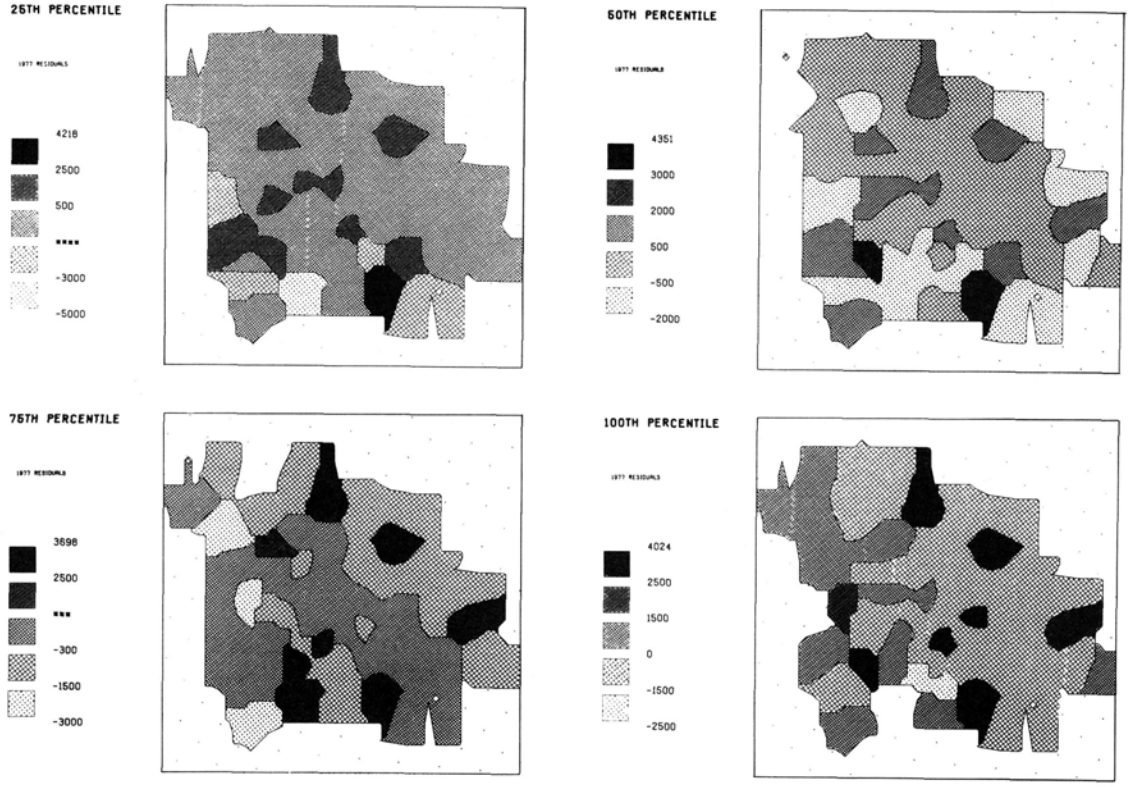

Figure 3. **Automated "proximal" representation of trend surface residuals for the outbreak period (cycle six).**

flection, saturation and waning phases of the 1977-78 epidemic of Hepatitis A. Once again, variance explained generally decreased as the disease spread through the city from one quartile to the next. However, most of the fourth degree surfaces explained nearly half of the variance regardless of the phase of the epidemic.

Residual maps were also developed using GRIDSHADE, and these are depicted in Figure 4. The patterns for each of the four phases are not always similar; however, the twenty-fifth and hundredth percentile residual patterns appear to coincide. Results of regression testing wherein the residuals from the first five cycles were compared with those for the outbreak cycle indicated that the best correlation resulted with the twenty-fifth (.55) and the hundredth (.55) percentiles. The correlation for the fiftieth percentile was about .35 and that for the seventy-fifth percentile only .20. These findings support the suggestion previously made that the hundredth percentile distributions of one cycle of the disease may be better indicators of the twenty-fifth percentile distributions of the next than the distributions shown by intermediate quartiles. In other words, it may be easier to determine where an epidemic is going to begin than the actual direction of diffusion that might take place during any given cycle.

Conclusions

The intent of this paper has been to illustrate some applications showing how contemporary methods in spatial analysis can be systematically linked with automated geographic base files and computer mapping techniques to examine general epidemiological aspects of an infectious disease. The methodology used within this study suggests one way that this can be accomplished to monitor disease diffusion within cities. Processing the case records within the Akron SMSA DIME/ADMATCH system and utilizing these geographically-aggregated disease data with SYMAP and GRIDSHADE provide an important graphic medium for inspecting diffusion patterns.[6]

"Predictive" aspects of this system have definite limitations, as has been demonstrated. One problem is the very nature of the HAV agent. As the various types of hepatitis and their accompanying sub-determinants are better understood, reporting should improve substan-

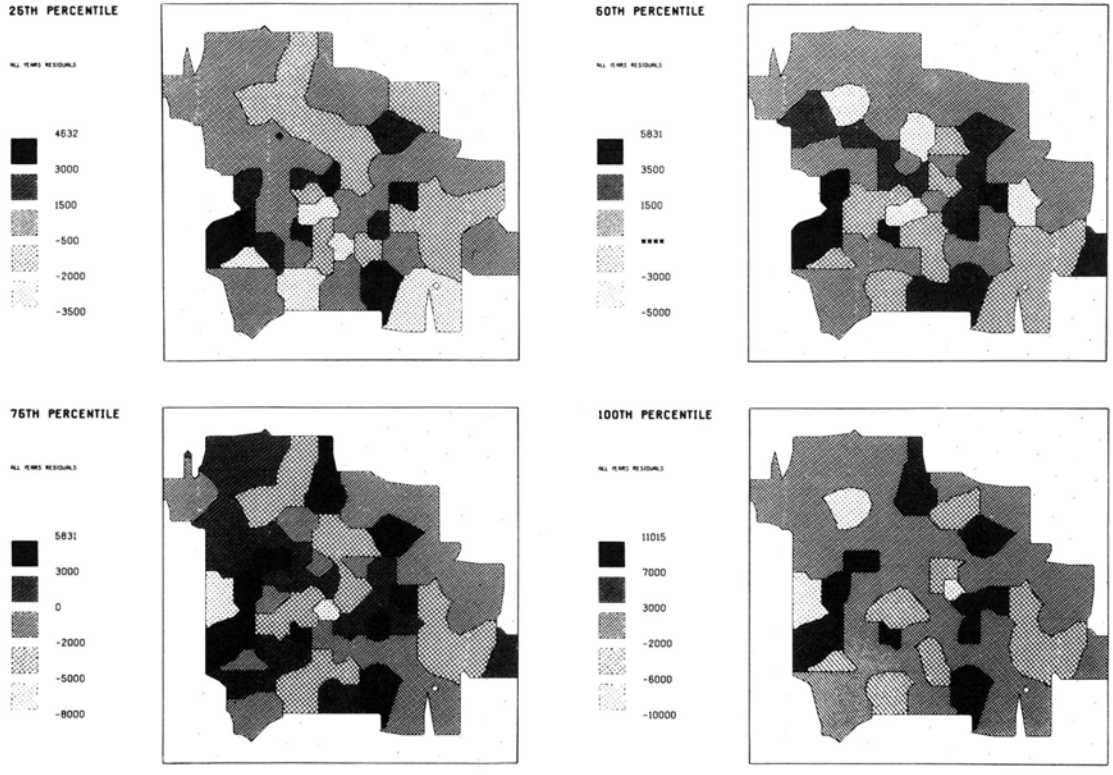

Figure 4. Automated "proximal" representation of trend surface residuals for the first five cycles.

tially. There remains the problems of subclinical cases and the long incubation period that must be coped with in trying to monitor the spread of the disease. Also, patterns of urban behavior resulting in human contact fluctuate daily as well as over longer periods of time, thus complicating this scale of diffusion analysis. However, improved reporting can lead to the use of more sophisticated time series techniques in actually forecasting future outbreaks of Hepatitis A.

Footnotes

1. Presumably, most of the reported cases considered "Infectious Hepatitis" or "Hepatitis A" were episodes resulting from HAV infections. See World Health Organization, Advances in Viral Hepatitis, Report of the WHO Expert Committee on Viral Hepatitis, Geneva, 1977 and James E. Maynard, "Hepatitis A," Yale Journal of Biology and Medicine, Vol. 49 (1976), pp. 227-233.

2. Gerald F. Pyle, Applied Medical Geography, Washington: V.H. Winston and Sons, 1979, Chapter 5.

3. A.A. Brownlea, "Modelling the Geographic Epidemiology of Infectious Hepatitis" in N.D. McGlashan, Medical Geography: Techniques and Field Studies, London: Methuen & Co., Ltd., 1972, pp. 279-300.

4. Examples of such analyses include: Joseph L. Melnick, Charles P. Gerba and Craig Wallis, "Viruses in Water," Bulletin of the World Health Organization, Vol. 56 (1978), pp. 499-508 and Barry S. Levy, Robert E. Fontaine, Clarence A. Smith, James Brinda, Gladys Hirman, David Nelson, Peter Johnson and Oren Larson, "A Large Food-Borne Outbreak of Hepatitis A," Journal, American Medical Association, Vol. 234 (1975), pp. 289-294.

5. Kurt E. Brassel, "Shaded Maps From Raster Data," Technical Report, Geographic Information Systems Laboratory, Department of Geography, State University of New York at Buffalo, 1979.

6. Kurt E. Brassel and Jack J. Utano, "Mapping From An Automated Display System," The Professional Geographer, Vol. 31 (1979), pp. 191-200.