

Navigating an outbreak: geospatial methods for STI outbreak investigations

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Outbreaks of sexually transmitted infections (STIs) are a continued public health concern. In this issue, for example, Foster and colleagues describe an outbreak of gonorrhoea that affected over 300 people in a discrete population in England, predominantly young heterosexual adults.¹ Outbreaks of other emerging, or re-emerging, infections such as shigella² and syphilis³ have also been detected with increased regularity, while the recent evolution of a 'highly resistant' strain of gonorrhoea in the north of England generated considerable media coverage due to the threat of spread of antimicrobial resistance.⁴ Social networking apps that use geographical locations to find sexual partners are thought to have contributed to the spread of some of these infections, partly because they can increase the size and connectivity of sexual networks. Consideration of geographical information is therefore important when investigating STI outbreaks.

In a previous editorial in *Sexually Transmitted Infections*, Simms and colleagues outlined the potential for geospatial methods to be applied across sexual health research.⁵ They identified examples of researchers using these tools to map geographical distributions of infection; plan, improve and evaluate services, and identify clusters of STIs in space and time. Here, we focus specifically on methods that can be used to enhance outbreak investigations. Many geospatial tools are available and can be used to assist with detection of the outbreak; describing cases; testing hypotheses; targeting interventions and communicating findings. These approaches are summarised in table 1 and described in detail in a recent systematic review.⁶ However, only one of the reports identified in this review described an investigation of an STI outbreak, indicating an

opportunity for expansion of their use in this field.

IDENTIFYING THE OUTBREAK

Outbreak investigations are prompted when an unusual increase in cases of disease is identified. In the study described by Foster and colleagues, this occurred when local clinicians recognised a rise in the number of cases of gonorrhoea in their jurisdiction and a change in their characteristics. In situations such as this, simple geographical visualisations can be useful in assisting with ascertainment of the outbreak. Dot maps, for example, show the locations of cases and can be colour coded according to their characteristics, helping to highlight similarities and differences between cases. Interactive tools for producing such maps are becoming increasingly available,⁷ offering the potential for these maps to be generated and interrogated without the need for expertise in geographical information systems. Since dot maps do not account for the underlying distribution of the population, it is useful to test whether the suspected increase in cases within an area is statistically significant. This can be done using a cluster detection method such as the spatial scan statistic.⁸

DESCRIBING CASES AND GENERATING HYPOTHESES

Maps can also play a key role in describing outbreak cases, for example by displaying the relative incidence of disease in different areas. If administrative boundaries are used to define these areas, maps of incidence rates can be produced based on population denominators. 'Thematic' maps can also be generated using the same boundaries to describe the populations that live in the areas using demographic or other routinely collected data such as vaccination rates or socioeconomic status. Thematic maps may also provide alternative explanations for an apparent rise in cases, such as changes in testing rates or population demographics.

An alternative to visualising incidence based on administrative areas is to generate smoothed incidence maps using point locations. These maps display the spatial

intensity of cases, using methods such as kernel density estimation and P-splines, and can be particularly useful to describe the progression of an outbreak over time. A simple demonstration of this can be seen in an investigation by Norstrom and colleagues into an outbreak of acute respiratory disease in Norwegian cattle herds.⁹

TESTING HYPOTHESES

Spatial analytic methods can then be used to test hypotheses generated during outbreak investigations. For example, in the investigation by Foster and colleagues, they hypothesised that the gonorrhoea outbreak was circulating in young heterosexuals in a localised area. A test of spatial clustering could have been used to investigate this hypothesis by comparing the geographical concentration of cases in this group with those in a control group, such as men who have sex with men. The specific method chosen would depend on whether point locations or area data were available; and whether they were interested in identifying evidence of clustering over the entire study area ('global' tests), or in locating specific clusters ('local' tests).

Spatial modelling methods can be used to gain insights into areas likely to be at risk. Geographic profiling, for example, is a novel modelling tool that aims to identify potential venues of transmission using locations of epidemiologically linked cases.¹⁰ This method may have helped in a recent investigation of hepatitis B infection in men who have sex with men, in which a truck stop was implicated as a common transmission venue.¹¹

COMMUNICATING FINDINGS AND TARGETING INTERVENTIONS

Maps can provide a very effective means of communicating findings from an outbreak investigation, and may be designed for use by health professionals, policy makers or the general public. During the recent international outbreaks of Zika and Ebola virus disease, for example, 'real-time' online interactive maps have been produced that clearly displayed the main areas affected and could be accessed by anyone.^{12 13} Plotting locations of services can also help with targeting interventions, for example, by identifying suitable areas for outreach work or determining where additional clinic sessions may be beneficial.

In their investigation of a gonorrhoea outbreak, Foster and colleagues used an innovative means of communicating health promotion messages, by targeting

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Table 1 Examples of geospatial methods classified by type and their application to outbreak investigations

Geospatial methods	Stage in outbreak investigation				Communicating findings; targeting interventions
	Identifying outbreak	Describing cases	Generating hypotheses	Testing hypotheses	
Visualisation	Dot map; rate map	Thematic map; smoothed incidence map	Voronoi diagram		Mapping affected areas and locations of services
Exploration		Spatial averages; spatial case definition		Spatial attack rate comparison	Spatially targeted information
Cluster detection	Spatial scan statistics		K-function analysis	K-nearest neighbour test; Knox test; Moran's I	
Modelling			Geographical profiling	Dispersion modelling	Risk maps

users on social media based on their age and post code of residence. Including simple maps within these messages that show the areas most at risk may be an effective approach to further increase engagement in similar campaigns in the future.

CHALLENGES AND OPPORTUNITIES

There are also limitations to the methods of geospatial analysis described here. Protection of patient confidentiality is clearly an important consideration, and maps must be produced at an appropriate level of resolution to avoid deductive disclosure. For this reason, precise spatial data are not always available to local public health professionals through surveillance systems, which limits the analytic methods that they can carry out. If point locations such as post codes are unavailable, analyses can be conducted on areal-level data. However, these displays are susceptible to the ecological fallacy (the assumption that an individual's characteristics are the same as those for the group to which the individual belongs), and the modifiable aerial unit problem (that patterns are sensitive to changes in the boundaries into which they are grouped). It should also be acknowledged that geospatial analyses alone are not sufficient for outbreak investigations, and must be combined with classic epidemiological analyses to gain robust conclusions.

Further developments in geospatial data collection in STI surveillance systems could facilitate more effective outbreak investigations in future. Collection of additional information such as partner meeting places, for example, could aid

targeting of preventative interventions and improve case finding. This may be particularly important if use of social networking apps to find sexual partners leads to outbreaks being spread over a larger area than was previously common. Integration of map interfaces to data collection systems may provide a convenient and effective means of collecting, as well as analysing, such data, and allow routine interrogation of information presented on maps. Another development that could improve the understanding of geographical information in STI outbreak investigations in future would be combination with molecular typing data. Cases with an indistinguishable molecular strain type that are also close in space are more likely to be linked through transmission and are therefore a potential target for control measures.

In summary, many geospatial methods are available that could provide useful means of visualising, describing and analysing data during STI outbreak investigations. Expanding the use of these tools to complement traditional epidemiological analyses could allow earlier more precise detection of outbreaks and facilitate effective interventions for their control.

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