Infectious Outbreaks and Time-distributed Effects of Exposure

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OBJECTIVE

The objective of this communication is to demonstrate an approach for modeling time-distributed effects of exposures to cases of infection which can be utilized in syndromic surveillance systems for characterizing, detecting, and forecasting a potential outbreak.

BACKGROUND

In our recent work we have outlined the framework for modeling outbreaks of waterborne and food-borne infections based on the notion of a disease "signature" and have suggested a number of techniques to characterize lagged exposure-outcome relations. We assumed that in susceptible populations an observed effect of exposure to a specific pathogen is distributed over a range of time lags. The mean incubation period for food- or waterborne infections may vary from one or two days for some viral infections to two weeks for giardiasis. For each infection, individual incubation time depends on individual susceptibility to the pathogen, dose of pathogens and other factors. If person-to-person transmission is low, a temporal pattern of observed cases following an episode of exposure may resemble a distribution of pathogen-specific incubation time.

In our early studies of the Milwaukee outbreak of cryptosporidiosis we have demonstrated a delayed effect of a spike in drinking water turbidity on the incidence of non-specific gastroenteritis. We assumed that a uniform approximation to the lag structure was sufficient for the existing outcome, i.e. non-specific gastroenteritis, since an outcome variable represented a mixture of diseases caused by a wide range of pathogens. We have also developed an approach to visualize the lagged relations using the Temporal Exposure Response Surfaces (TERS), which allowed us to describe the lagged structure of a health outcome in response to elevated water quality parameters. Our further analysis of reported distributions of incubation periods for cryptosporidiosis supported the idea of considering the knowledge of distributions for incubation periods in the time series analysis.

METHODS

Models that account for time-distributed delays were introduced four decades ago in the econometric literature and are widely implemented in many practical applications. The model we have developed uses the weights for each lag estimated from the Poisson distribution with a parameter corresponding to a disease-specific mean incubation period in the population.

RESULTS

We demonstrated the proposed approach using simulated and actual surveillance data within a testing framework utilizing environmental data on ambient temperature and reported cases of enterically-transmitted infections. Extensive simulations were conducted to examine model sensitivity to response magnitude, exposure frequency, and extent of latent period.

CONCLUSIONS

The study emphasizes importance of accounting for potential delays in reporting, seasonal fluctuations in the incidence of enteric infection, and mixtures of infections with different incubation periods. The potential for the proposed approach is evident by our recent development of a system of adaptive algorithms for detecting and forecasting waterborne outbreaks, where we introduced a notion of a disease "signature" to express manifestation of infection in response to an agent and incorporated this disease "signature" into short-term and long-term forecasts.