Traveling Epidemic Waves in Biosurveillance Data: Identifying Early Hotspots of Respiratory Illness

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OBJECTIVE

To characterize yearly spatial epidemic waves of respiratory illness to identify early hotspots of infection.

BACKGROUND

We have previously shown that timeliness of detection is influenced both by the data source (e.g., ambulatory vs. emergency department)[1] and demographic characteristics of patient populations (e.g., age)[2]. Because epidemic waves are thought to move outward from large cities[3], patient distance from an urban center also may affect disease susceptibility and hence timing of visits. Here, we describe spatial models of local respiratory illness spread across two major metropolitan areas and identify recurring early hotspots of risk. These models are based on methods that explicitly track illness as a traveling wave across local geography.

METHODS

We examine respiratory chief complaint data from emergency department (ED) visits at two major metropolitan tertiary care hospitals in Boston, MA and Washington, DC. Finite Fourier transforms were used to characterize the annual cycle of respiratory syndromes among patient subpopulations grouped by distance to city center. Cross-spectral analysis was used to find the estimated phase shift (i.e., lag or lead time) between the underlying yearly components of each of groups. We used Poisson regression to model lead time as a function of distance to city center and produce an estimate of the traveling wave of respiratory infection. Because these hospitals are positioned close to the city center, patients further from the center may be less likely to seek care at them -- there is a referral bias which must be accounted for as a confounding factor. The model accounts for referral bias by including the likelihood of a hospital visit based on the market share of a zip code. The model also includes census level demographic characteristics that may influence timeliness such as household size, population density and poverty level.

RESULTS

Local geography influences timeliness across both sites. Patients from urban areas present, on average, 8 days earlier than those from rural areas in each of the three metropolitan areas. After accounting for the confounding by referral bias and demographic factors, we find that distance from city center plays a major role in timing of presentations of respiratory illness in Boston (P=0.0049) and Washington, (P=0.0037). We estimate that the rate of the traveling wave of infection from city center is approximately 2.0 km/day in both cities. Further, we find that both large household size and high population density are statistically significant indicators of early presentation.

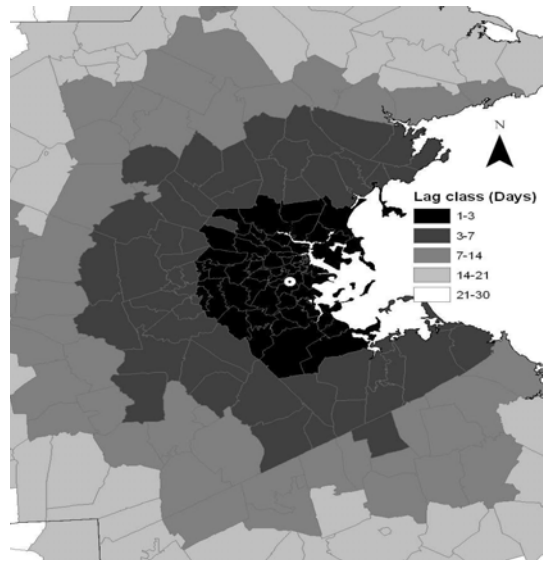

Fig. 4: Predicted timeliness of respiratory illness by zip codes surrounding Boston, MA. Seasonality ranges from early transmission (dark) to late transmission (light).

CONCLUSIONS

Modeling the spatiotemporal patterns of respiratory syndrome in metropolitan areas reveals the important effect of location on the timing of presentation to healthcare settings. Urban centers with high population density may represent the starting point for waves of respiratory epidemics. Timeliness of outbreak detection may be improved with special focus on these hotspots.

REFERENCES

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