Use of time series models for multi-stream surveillance

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Objective

This paper describes the use of time series models for simultaneous monitoring of multiple streams of influenza surveillance data.

Background

Surveillance of individual data streams is a well-accepted approach to monitor community incidence of infectious diseases such as influenza, and to enable timely detection of outbreaks so that control measures can be applied. However the performance of alerts may be improved by simultaneously monitor a variety of data sources, or multiple streams (eg from different geographic locations) of the same type, rather than monitoring only aggregate data. Rates of influenza-like illness in subtropical settings typically show greater variability than in temperate regions [1].

Methods

We studied nine annual cycles of sentinel surveillance data on influenza-like illness consultation rates in outpatient clinics in four geographic areas under two surveillance networks, namely GPs and GOPCs (a total of 8 streams). We used dynamic linear models, a class of state space models which can track trends and variances in time series data, on the multi-stream (multivariate) and aggregated (univariate) data, and we determined that an aberration had occurred when the current observation fell outside a forecast interval generated by the model. For simultaneous monitoring of all 8 data streams, we monitored separate aberrations as above and generated alerts based on the first occurrence of any aberration (M1), 2 simultaneous aberrations (M2), the first occurrence of 3 simultaneous aberrations (M3), any 2 aberrations within a 2-week period (M4), and any 3 aberrations within a 2-week period (M5). We compared the performance of alerts generated by the various alternative approaches by calculating area under the ROC curves versus laboratory data as the gold standard, weighting for timeliness [2].

Results

The best AUWROC from each of the data streams was produced by the GP New Territories East data, which outperformed the aggregate GP data. Conversely, for GOPC data, the performance of alerts generated from the aggregate data was superior to that of any single geographical GOPC data stream. When we combined alerts from univariate (independent) models for each data stream, methods based on simultaneous alerts performed well. The optimal methods were M2 and M3 with AUWROC of 0.89 and 0.90 and timeliness of 1.22 and 1.47 weeks, respectively, for a fixed specificity of 0.95. In general, univariate models outperformed multivariate models [3].

Discussion

Monitoring multiple geographic streams of sentinel data for 2 or 3 simultaneous aberrations provided substantial improvements in AUWROC and also in timeliness for a fixed specificity when compared with monitoring aggregated data or any single data stream alone. We also applied multivariate models with various alternative correlation structures, but use of these more complex models did not appear to improve performance, possibly because correlation between the surveillance data streams varied from year to year, whereas the multivariate model is based on constant correlations. Our results based on dynamic linear models could be compared with results under simpler models such as control charts, CUSUM, simple regression, and alternative strategies for combining p-values and synthesizing multiple data streams.

References

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