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Major Article

Hand hygiene compliance surveillance with time series anomaly detection

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Background: Hand hygiene is the most important intervention to reduce the risk of transmission of pathogens in health care. Assurance of effective hand hygiene improvement campaigns includes adequate data analytics for reporting compliance. Traditional analytical approaches for monitoring hand hygiene compliance suffer from several limitations, including autocorrelation. The objective of this study was to use a novel time series anomaly detection algorithm to analyze routine hand hygiene compliance data.
Methods: Hand hygiene compliance data were collected daily by trained observers in a large academic medical center. Statistical process control p-charts were used as a comparison method of analysis per facility protocol. Time series anomaly detection was carried out using the seasonal and trend decomposition using LOESS (STL) algorithm.
Results: A total of 34 months of hand hygiene compliance data were analyzed. Traditional statistical process control p-charts identified over 76% of rates as special-cause variation, whereas STL identified 18% of rates as anomalous.
Conclusions: This study supports the use of time series anomaly detection for the routine surveillance of hand hygiene compliance data. This method will facilitate specific and accurate feedback, helping to improve this critical approach for improving patient safety.

BACKGROUND

Hand hygiene is the most important intervention to reduce the risk of transmission of pathogens capable of causing health care–associated infection.[1] Because health care–associated infections have been estimated to cost the US health care system nearly $10 billion annually[2] and have staggering mortality,[3] it is critical to implement effective multimodal campaigns with appropriate feedback.[4] To ensure that hand hygiene campaigns are effective, hand hygiene compliance must be routinely measured and reported. Measurement of compliance with hand hygiene recommendations is typically accomplished through in-person observation or through automated monitoring systems.[5-7] Regardless of the data collection mechanism, data analytics are key to understanding these observational data. Basic data visualizations such as bar, line, or statistical process control charts[8-12] are traditionally utilized to track the ongoing rates of hand hygiene compliance.[13,14] These methods can suffer from several limitations, such as the inability to deal with autocorrelation (eg, recent rates are correlated with current rates and less so with more historical rates) and false-positive detection of special-cause variation, particularly when the number of observations is large.[15] Fortunately, methods such as time series anomaly detection provide effective and efficient methods for reducing these issues. As far as we know, no studies have utilized time series anomaly detection for routine monitoring of compliance with hand hygiene recommendations. The objective of this study was to demonstrate the utility of time series anomaly detection for routine surveillance of hygiene compliance.

METHODS

Study design

This was an observational study using routine hand hygiene compliance data from a 356-bed, urban, academic medical center that were collected from January 1, 2016, through October 31, 2018.

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Hand hygiene monitoring

Hand hygiene compliance data were collected daily by compensated independent observers on a random basis. Observers were trained by infection prevention and control staff prior to any data collection. Hand hygiene compliance was documented using the iScrub mobile application[16] and transferred to a flat file spreadsheet for analysis. Compliance upon entrance to and exit from patient rooms was evaluated.

Statistical analysis

Statistical process control p-charts were used as a comparison method of computational surveillance per facility protocol. Time series anomaly detection was carried out using the seasonal and trend decomposition using LOESS (STL) algorithm. R version 3.5.2 (R Foundation for Statistical Computing; Vienna, Austria) was used for all analyses.

RESULTS

Data were collected daily at random time intervals 24 hours a day from January 1, 2016, through October 31, 2018. There was an average of 1561 observations per month (SD = 993), with an average of 901 (58%) compliant observations (SD = 592). A web application to automate the creation of time series anomaly detection charts is available on the IPStat analytics toolkit website: http://capo.ctrsu.org:3838/shiny/ipstat/. A total of 34 months of hand hygiene compliance data were analyzed. Figure 1 depicts the trend of hand hygiene compliance rates with exact 95% confidence intervals. Traditional statistical process control p-charts identified over 76% of the rates as special-cause variation (Fig 2). Time series anomaly detection identified 18% of the rates as anomalous (ie, abnormal) (Fig 3). All periods identified as anomalous on the time series anomaly detection chart were also identified as special-cause variation on the statistical process control chart.

DISCUSSION

This study supports the use of time series anomaly detection for hand hygiene monitoring. This method appears to provide more specific detection of abnormal hand hygiene compliance rates compared to statistical process control charts. Because of this, time series methods may be more appropriate for use in certain situations. Without utilization of appropriate analytical methodologies for hand hygiene compliance data, it may be impossible to understand the trajectory of compliance. In the statistical process control chart, nearly every point was identified as special-cause variation. This makes this approach impractical for the practitioner, as a stable baseline is necessary to accurately detect special-cause variation, resulting in the available data being inappropriate for statistical process control. Even if these points were indicative of special-cause variation, it would appear that every month either interventions to understand higher than normal rates or interventions to improve hand hygiene rates would have to be developed and implemented. This is not a realistic approach in practice and reduces the utility of these methods for routine use. Further, because feedback is an important component of sustainable multimodal hand hygiene interventions,[17] supplying accurate information to those observed is critical. Here, we report that time series anomaly detection delivers a more specific identification of potentially abnormal compliance rates, providing a more focused visualization for accurate feedback to those observed. It is important to note that, just because a particular analytical approach does not detect an abnormal rate (an anomaly or special-cause variation), it does not mean that interventions should not be undertaken. Even in times when all the rates are normal, it is possible that the rates are too low overall (with hand hygiene compliance) or too high (for infection rates). Therefore, care must always be taken to evaluate the data statistically as well as through a clinical lens.

There are many reasons why time series anomaly detection may be better suited for hand hygiene compliance data, including the capability to identify anomalous points when seasonality or autocorrelation of the compliance metrics are present. In fact, hand hygiene compliance does appear to exhibit distinct seasonal and autocorrelative behaviors.[18,19] There are many reasons why this may be the case; for example, seasonal variation in the acuity of patients may affect the focus or time necessary to perform adequate hand hygiene among health care workers in trauma centers.[20] Further, various groups of health care workers (eg, physicians, nurses, pharmacists) often exhibit different and correlated rates of hand hygiene within their groups.[21,22] These factors may increase the autocorrelation of compliance rates and underscore the need for analytical approaches accounting for these issues.

This study has several limitations. First, it is a single-center study from an urban, academic medical center. Because of this and the factors described previously, the methodology may not be generalizable

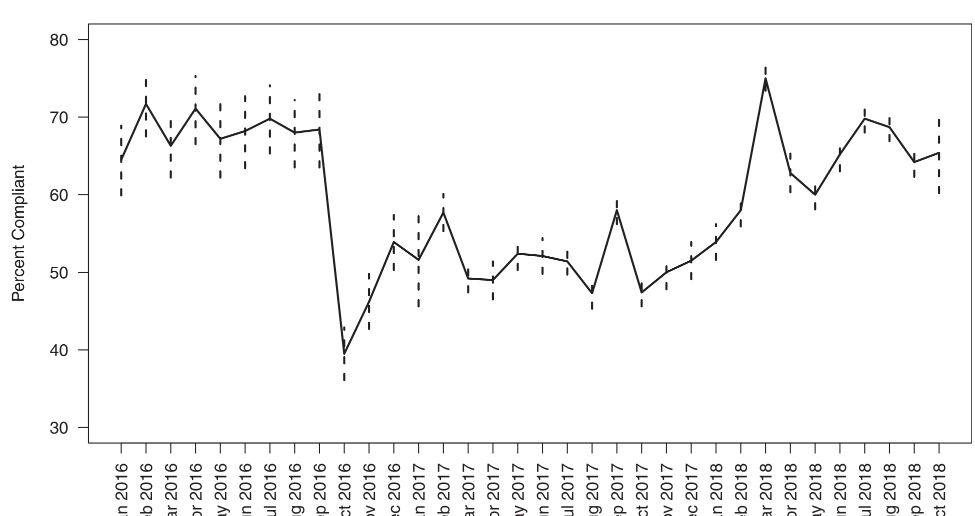

Fig 1. Line chart for computational hand hygiene surveillance with exact 95% confidence intervals. Dotted vertical lines represent 95% confidence intervals.

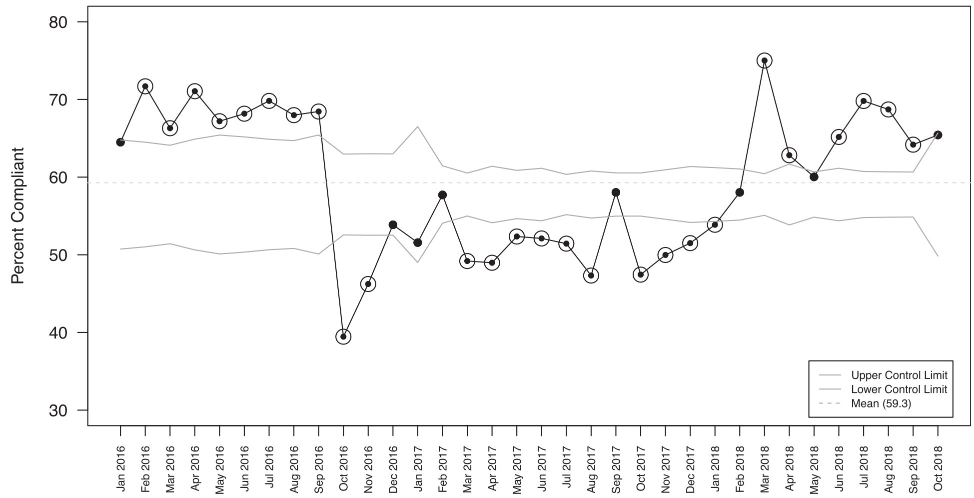

Fig 2. Statistical process control p-chart for computational hand hygiene surveillance. Circles represent detection of special-cause variation.

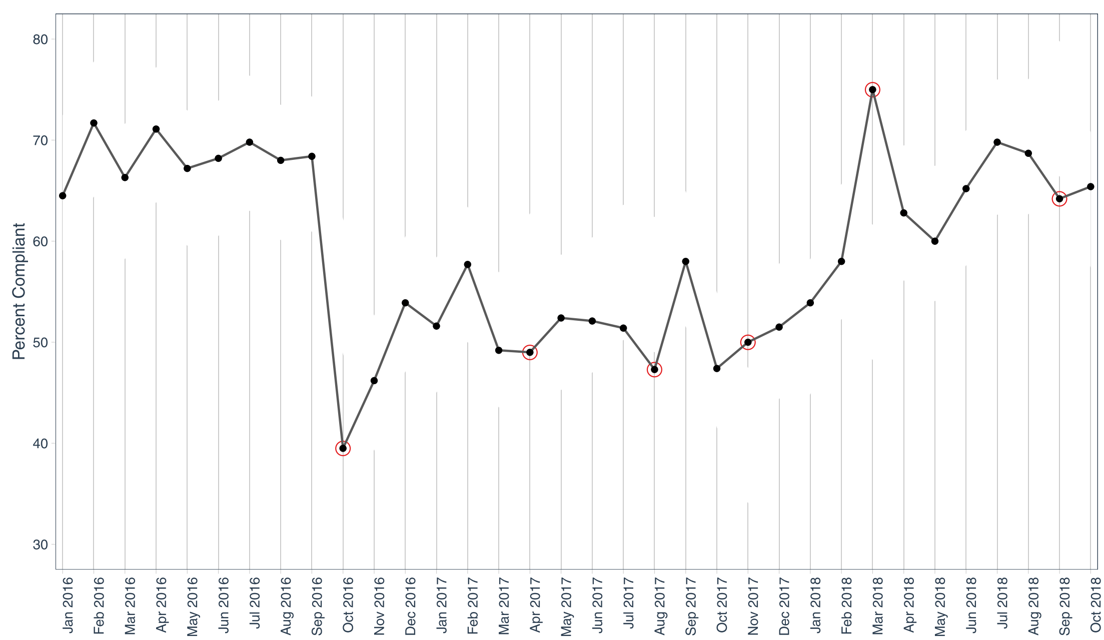

Fig 3. Time series anomaly detection for computational hand hygiene surveillance. Circles represent detection of special-cause variation.

to other areas. Second, we did not compare the time series methodologies to more sophisticated statistical process control charts. The rationale for this was that these charts are rarely used in health care, and their use typically requires several charts to be constructed to understand the data. For example, cumulative sums or exponentially weighted moving average[23] process control charts may be able to filter out some autocorrelation; however, their use would also require a traditional Shewhart p-chart to understand anomalous data points. Another limitation is the use of hand hygiene observers. Although observers made attempts to be covert, the Hawthorne effect may have instilled an unmeasured bias[24-26] leading to detection of false-positive or -negative anomalies.

Future studies should determine the utility of these methods in non-urban trauma centers. Another area in need is prospective data collection along with intervention development and implementation. In this context, we may be able to identify true and false-positive anomalies.

CONCLUSIONS

This study supports the use of time series anomaly detection for the routine surveillance of hand hygiene compliance in health care. Single interventions are unlikely to sustainably improve hand hygiene in health care settings. With a better understanding of compliance in any particular facility and the ability to provide accurate, targeted feedback, tailored interventions may be developed to improve this critical approach for improving patient safety.

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