ORIGINAL ARTICLE

Evaluation of Healthcare-Associated Infection Surveillance in Pennsylvania Hospitals

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(See the commentary by Baier and Gravenstein, on pages 112–113.)

OBJECTIVE. In Pennsylvania, reporting of healthcare-associated infections (HAIs) was mandated in 2007, and hospitals were encouraged to implement qualified electronic surveillance (QES) systems to assist HAI detection. This study evaluated the usefulness of these systems in reducing HAIs.

DESIGN. Online survey and retrospective cohort study. Eligible facilities had a QES or manual system in place for the entire study period and sufficient data in selected hospital units.

METHODS. Surveys were sent to infection preventionists (IPs) in all Pennsylvania hospitals to gather qualitative information about their systems. National Healthcare Safety Network data from Pennsylvania hospitals for July 2008 through June 2010 were used to compare catheter-associated urinary tract infection (CAUTI) rates in facilities with and without a QES system.

PARTICIPANTS. IPs from 174 facilities responded to the survey. Data from 119 of 234 hospitals were analyzed.

RESULTS. IPs in facilities with a QES system reported spending as much time on data management and education as IPs in hospitals with manual surveillance. Significant interaction was observed in CAUTI rates over time between groups of facilities with and without a QES system after controlling for device-utilization ratio, location within hospital, and licensed bed size ($P < .01$). QES hospitals showed a significant decline in CAUTI rates ($P < .01$); manual surveillance facilities showed no change in rates ($P > .05$).

CONCLUSIONS. Over the 2-year period, a significant decline in CAUTI rates was observed in facilities with a QES system. This suggests that electronic systems may aid in reducing HAI rates. Additional data are needed to see whether these improvements and trends persist.

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Healthcare-associated infections (HAIs) substantially impact the disease burden in the United States, with approximately 1.7 million HAIs and 100,000 deaths each year.[1] To reduce the number of HAIs, hospitals must track the number, type, and location of infections occurring in their facility to effectively target prevention efforts. Surveillance systems help identify patients who become infected during hospitalization or enter the facility with preexisting infections, enabling healthcare workers to take proper precautions to limit the spread of infections. Electronic surveillance systems can potentially help facilities improve infection prevention by automating surveillance and reporting, reducing human error in applying complicated definitions and enabling infection preventionists (IPs) to dedicate more time to infection prevention. However, these systems are costly, and few studies have attempted to evaluate their effectiveness.[2,3]

In 2004, the Pennsylvania Healthcare Cost Containment Council began collecting HAI data from all Pennsylvania hospitals and publicly reporting minimally risk-adjusted facility-specific information. In July 2007, Pennsylvania's legislature passed the Healthcare Infection Prevention and Control Act (Act 52) to help reduce and prevent HAIs.[4] Act 52 mandated that Pennsylvania hospitals report all HAIs using the Centers for Disease Control and Prevention's (CDC's) National Healthcare Safety Network (NHSN) in lieu of previous data submission methods to the Pennsylvania Healthcare Cost Containment Council. Data collection under Act 52 began in February 2008. Pennsylvania requires that hospitals collect patient-days for all inpatient units and device-days for all units where patients have either urinary catheters or central lines. Urinary tract infections are one of the most common types of HAIs reported in Pennsylvania; more than half of all healthcare-associated urinary tract infections are catheter associated.[5,6] Rates for catheter-associated urinary tract infections (CAUTIs) are calculated using device-days (catheter-days) as the denominator. Having facility-wide denominator

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TABLE 1. Facility Counts from Survey and Data Analysis

	Responses to survey	Complete data for analysis
Manual system (n = 107)	81 (76)	72 (67)
QES system (n = 49)	36 (73)	47 (96)
Adopted QES system at another time[a] (n = 78)	57 (73)	0 (0)
Total (n = 234)	174	119

NOTE. Data are no. (% of row). QES, qualified electronic surveillance.
[a] Includes facilities that adopted systems after July 2008 but before June 2010.

data enables consistent calculation of overall rates of CAUTIs, which is one of the benchmark infections chosen for public reporting. In 2009, Pennsylvania reported 25,914 infections, of which 3,935 were CAUTIs.[6]

Act 52 also specifies that hospitals must assess the feasibility of implementing a qualified electronic surveillance (QES) system to identify HAIs. To date, Pennsylvania is the only state to include a provision for electronic surveillance in its legislation.[7] Per the legislation's requirements, QES systems must perform extractions of existing electronic clinical data; translate nonstandardized laboratory, pharmacy, or radiology data into uniform information; collect patient-specific data for the entire facility; and provide clinical support, educational tools, and training as well as clinical improvement measures.[4]

Prior to Act 52, only 46 of the 255 hospitals in Pennsylvania had a QES system in place. Subsequently, an additional 89 hospitals installed or made plans to install electronic systems. Some hospitals anecdotally reported that the added benefits of such systems had been marginal and did not outweigh the costs. Therefore, we conducted an evaluation of these electronic systems to assess differences in the utility of the surveillance systems used by Pennsylvania hospitals. We also aimed to determine whether hospitals with electronic surveillance systems report higher rates of CAUTIs to the NHSN than those facilities with manual processes of identifying infections. Additionally, changes in rates of CAUTIs over time for facilities with a QES system were compared with those for facilities without such systems.

TABLE 2. Descriptive Characteristics of Facilities by Group

	QES (n = 47)	Manual (n = 72)	P
Bed size			<.01
<50 beds	1 (2)	24 (33)	
50–99 beds	8 (17)	19 (26)	
100–249 beds	18 (38)	23 (32)	
250–499 beds	10 (21)	2 (3)	
>500 beds	10 (21)	4 (6)	
Urban vs rural[a]			.10
Urban	43 (91)	58 (81)	
Rural	4 (9)	14 (19)	
Medical school affiliation			<.01
Yes	26 (55)	10 (14)	
No	21 (45)	62 (86)	

NOTE. Data are no. (%), unless otherwise indicated. QES, qualified electronic surveillance.
[a] Urban versus rural status is based on the facility lying within an urban area as defined by the US Census Bureau.

METHODS

Data Sources

Phone interviews were first conducted with IPs to gather information about infection surveillance as part of their daily duties. After gathering initial information, voluntary online surveys were sent in 2010 to IPs at all hospitals to obtain information about their specific systems and time invested in infection surveillance. An online survey tool was used to gather quantitative and qualitative responses related to data collection and reporting (SurveyMonkey).

To assess trends in infection rates, infection counts and device- and patient-day data were obtained from the NHSN from July 2008 through June 2010. Internal validation of NHSN data for Pennsylvania was conducted from July 2008 through December 2009; data from January 2010 through June 2010 have been internally validated but are considered preliminary until the release of Pennsylvania's 2010 report on device-associated infections. Internal validation consists of identifying and notifying hospitals of potential data errors in the NHSN and allowing those hospitals to correct any confirmed errors before data are published.[6] Additional facility-level risk factors, such as licensed bed size and medical school affiliation, were obtained from the results of annual surveys completed by facilities in the NHSN. Urban and rural status of facilities was determined on the basis of the location of each hospital inside or outside of an urbanized area, as defined by the US Census Bureau in the census of 2000.[8] Hospitals were mapped using ArcGIS for Desktop software (Esri). Hospitals within an urbanized area were classified as urban, and those outside of an urbanized area were classified as rural.

Data Analysis

Statistical analysis of qualitative and quantitative data was performed using SAS, version 9.2 (SAS Institute). The t test was used to assess differences in selected survey responses. Descriptive statistics were generated using frequency procedures for all categorical variables. The χ^2 test was used to examine differences in characteristics between groups. Rates for CAUTIs were calculated using infection counts and

TABLE 3. Qualitative Survey Responses

	QES (n = 98)	Manual (n = 65)
No. of full-time IPs, no. (%)		
<1 IP	7 (7)	16 (25)
1–2 IPs	70 (71)	47 (72)
3–5 IPs	15 (15)	2 (3)
>5 IPs	6 (6)	0 (0)
Average reported percentage of time spent on tasks, %		
Data collection/entry	39	35
Data validation	22	27
Data reporting	19	15
Education and process improvements	29	33
Proportion of facilities with specific sources of automated data collection (n = 94), no. (%)		
Laboratory	89 (95)	...
Pharmacy	67 (71)	...
Radiology	45 (48)	...
Emergency department	40 (43)	...
Surgical	38 (40)	...

NOTE. IP, infection preventionist; QES, qualified electronic surveillance.

device-days (catheter-days). Infection events are considered CAUTIs in the NHSN if a patient has an indwelling catheter in place at the time of or within 48 hours before the onset of a urinary tract infection. Pooled infection rates were calculated for 2 groups of hospitals: (1) hospitals that had a QES system in place from July 2008 through June 2010, referred to as "QES facilities," and (2) hospitals that had not implemented an electronic system as of June 2010, referred to as "manual facilities." This differs from the qualitative analysis of survey results where facilities are grouped by self-report of having a QES system at the time of the survey in 2010. Device-utilization ratio (DUR), which measures the proportion of patients with certain devices, was calculated using device-days and patient-days (DUR equals device-days [eg, urinary catheter-days] divided by patient-days).

Denominator data (device-days and patient-days) were available only at an aggregate level by month for each location within a facility. Since no patient-level characteristics were available as risk factors, CDC location (a CDC-defined designation for patient care areas housing patients who have similar conditions or are receiving similar care) and facility-level data were used to control for differences in risk.[9] Poisson regression was used to model the infection count data with the total device-day data to determine differences in overall infection rates between the groups. Poisson regression was also used to model infection counts and device-days by month across the groups. To control for differences in types of facilities across groups, regression analysis was limited to those CDC locations with at least 5 infections and at least 5,000 catheter-days in each group. The adjusted, regressed rates by group were calculated for each month to compare changes in rates over time. A time variable of 1 year was also entered into a separate model in place of month to evaluate the validity of any results related to the time component because of the limited numbers of infections and catheter-days on a monthly basis. To further validate the findings, additional data analysis was conducted limiting the analysis to 6 CDC locations considered to be consistently present in facilities across both groups (medical critical care, medical/surgical critical care, surgical critical care, medical ward, medical/surgical ward, and surgical ward). Medical school affiliation, urban status, bed size, and DUR were entered into the models as potential confounders.

RESULTS

In total, 261 hospitals in Pennsylvania reported data to the NHSN from July 2008 through June 2010. Two hundred fifty of these hospitals were open during the entire period. Of the 250 facilities, 16 were excluded from the analysis because of incomplete or limited HAI data in the NHSN, leaving data from 234 facilities for analysis. Of these 234 facilities, IPs from 174 facilities responded to the survey, giving an overall response rate of 74%. Response rates varied by specific question; however, response rates did not vary notably between groups (Table 1). In July 2008, 51 (22%) of the 234 hospitals had a QES system in place. By June 2010, 128 (55%) of the hospitals had implemented such systems, meaning that more than half of Pennsylvania's hospitals utilize electronic surveillance of HAIs. One hundred fifty-six of 234 facilities had either a QES or a manual surveillance system in place for the entire period, and 119 of these facilities had data for patients in the CDC locations included in the analysis (Table 1). These facilities were used for the main quantitative analysis; descriptive characteristics are presented in Table 2. The distribution between the groups differed significantly for bed size

TABLE 4. Crude and Adjusted Rate Ratios (RRs) of Catheter-Associated Urinary Tract Infection (CAUTI) Rates for Qualified Electronic Surveillance (QES) versus Manual Systems

	RR (95% CI)
Crude association (QES vs manual)	1.00 (0.92–1.08)
Adjusted for DUR	1.02 (0.94–1.10)
Adjusted for DUR and CDC location	1.06 (0.97–1.15)
Adjusted for DUR, CDC location, and bed size	1.10 (1.01–1.20)
Adjusted for DUR, CDC location, bed size, month, and month-group interaction[a]	1.38 (1.18–1.62)

NOTE. CDC, Centers for Disease Control and Prevention; CI, confidence interval; DUR, device utilization ratio.
[a] Final model.

and medical school affiliation ($P < .01$). Infections and catheter-days attributed to the CDC locations included in the analysis, based on the infection and catheter-days criteria, represented 88% of CAUTI data reported to the NHSN for these facilities.

Survey Responses

Twenty-five percent of respondents from hospitals without a QES system reported having less than 1 full-time equivalent IP at their facility, compared with 7% of hospitals with a QES system (Table 3). IPs from hospitals with and without a QES system spent approximately the same amount of time on tasks such as data collection, entry, and reporting as well as education and process improvements (Table 3). Hospitals with a QES system reported spending less time on validation of their own data (22% vs 27%; $P < .01$). However, when responses for hospitals with a QES system were analyzed by how long a system had been in place, hospitals with a system in place for more than 1 year reported spending more time on education and process improvements than those with a system in place for less than 1 year (32% vs 24%; $P = .037$).

When asked whether the QES system assisted with the disease-reporting requirement in Pennsylvania, 68% of respondents replied that the system did assist with complying with reporting HAIs to the NHSN; 50% said it assisted with reporting notifiable diseases to Pennsylvania's Notifiable Electronic Disease Surveillance System. Additionally, 73% of respondents with a QES system reported that the system helped in decreasing HAIs. Finally, the majority of the respondents with a QES system had one that acquired data from their hospital's laboratory and pharmacy; less than half of the facilities received data from radiology, the emergency department, and/or surgical wards automatically (Table 3).

Analysis Results

Regression analysis of the crude rates of infection for the overall study period showed no difference in rates between hospitals with a QES system and those with a manual system (Table 4). DUR, CDC location, bed size, month, and month-group interaction were all significant confounders and were retained in the final model. Although urban status was a significant confounder of CAUTI rates, bed size and urban status were highly correlated; therefore, bed size was retained because it was a stronger regression ($P < .01$). In the final model, the month-group interaction was significant ($P < .01$), indicating a significant change in rates over time (Table 4). Figure 1 shows the final predicted rates, demonstrating

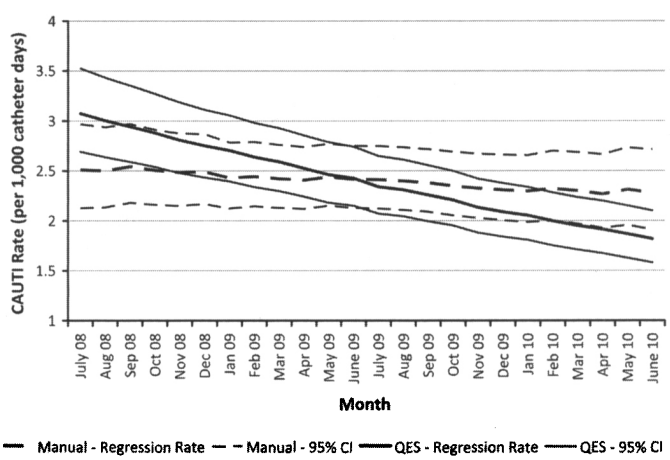

FIGURE 1. Regression of catheter-associated urinary tract infection (CAUTI) rates and 95% confidence intervals (CIs) by month.

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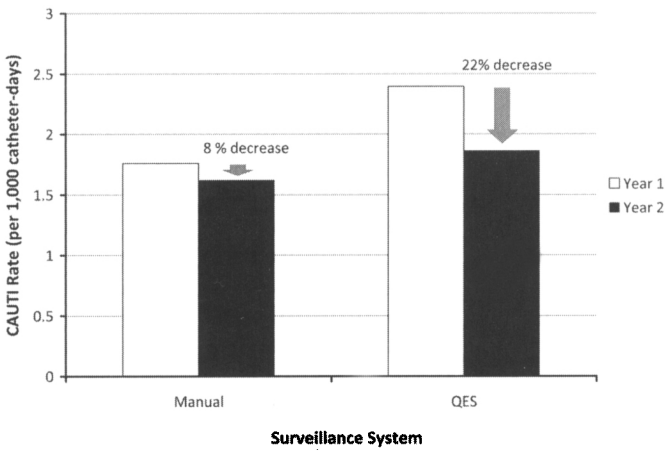

FIGURE 2. Crude catheter-associated urinary tract infection (CAUTI) rates by year and system.

the effect of the interaction and a steeper decline in rates for those hospitals with a QES system. When the model was run using year instead of month, similar results were obtained, and the year-group interaction was also significant ($P < .01$). Additionally, when the analysis was limited to the 6 CDC locations, the results were similar. In this limited-location model, the month-group interaction was borderline, not significant ($P = .059$); however, the year-group interaction was seen ($P = .043$). Since the interaction with a time variable was significant, overall comparison of infection rates cannot be interpreted.

To further evaluate the potential changes in rates over time, we looked at differences in crude rates between the 2 groups from the first year of data (July 2008–June 2009) compared with the second year (July 2009–June 2010). From year 1 to year 2, hospitals with a QES system experienced a 22% decrease in crude rates, whereas hospitals with manual surveillance experienced an 8% decrease (Figure 2). Data for each group of facilities were entered into separate regression models; the difference in rates from year 1 to year 2 was significant for hospitals with a QES system ($P < .001$) but was not significant for hospitals with a manual system ($P > .05$; Table 5).

TABLE 5. Changes in Catheter-Associated Urinary Tract Infection (CAUTI) Rates over Time by System

	IDR (95% CI)	*P*
Year 1 vs year 2		
QES change in rate	0.79 (0.73–0.85)	<.01
Manual change in rate (slope)	0.99 (0.86–1.13)	.85
Monthly		
QES change in rate	0.98 (0.97–0.98)	<.01
Manual change in rate (slope)	1.00 (0.99–1.01)	.63

NOTE. CI, confidence interval; IDR, incidence density ratio; QES, qualified electronic surveillance.

DISCUSSION

Although use of electronic surveillance systems in hospitals has increased over the last few years, this is the first study, to our knowledge, to explore the impact of these systems on their ability to decrease HAIs. Facilities with at least 1 full-time IP were more likely to have a QES system. This is not unexpected given that facilities with a QES system were more likely to be larger and have a medical school affiliation than facilities with a manual system. The finding that IPs in facilities with a QES system reported no difference in time spent on data collection and entry, reporting, or education and process improvements compared with facilities with manual surveillance was unexpected, although it was consistent with the results of a recent study.[10] One explanation is that facilities with a QES system might be identifying more infections and patterns, and so the efficiency gained is offset by the increase in data that must be managed.[10] Additionally, learning to navigate a new system to complete formerly routine tasks might increase the amount of time spent on these types of tasks.

The data were examined by the amount of time facilities had a QES system in place to try to understand whether the findings differed by how long a system was in place. The increase in time spent on education and process improvements for facilities with a system in place for more than 1 year implies that efficiencies may be gained when the system is no longer new. Despite the burden of time spent on various data tasks, the majority of respondents felt that their system not only helped them comply with NHSN reporting but also helped decrease HAIs.

The analysis of crude rates showed an almost 3-fold greater decrease from year to year for hospitals with a QES system compared with a manual system, even after controlling for multiple factors. Hospitals with a QES system showed a significant decline in CAUTI rates from year to year, whereas

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the decline in rates for hospitals with a manual system was not significant. Limiting the analysis to only those 6 CDC locations likely to be present across both groups showed consistent results, implying that this association is not the result of inherent differences in the types of locations between the groups.

These results suggest that QES systems may help decrease HAIs. Anecdotal assessments of individual systems in hospitals have reported that one of the most important features of electronic infection surveillance is the ability to follow a patient throughout their hospital stay. This allows staff to keep track of treatments, medications, and laboratory tests regardless of where the patient may be transferred without doing time-consuming chart reviews.[11-13] These systems can objectively scan and display the data, apply complicated definitions, and provide analytic support, leading to consistency in reporting and rapid identification of multidrug-resistant organisms or patterns of infection.[11,14] By producing ongoing alerts and reminders, infection prevention staff are kept aware of important infections present in their hospital. Examples of such notifications include prompting nursing staff to initiate contact precautions when multidrug-resistant organisms are identified, rather than waiting for physicians' orders, or automatically generating orders for cultures for patients who meet methicillin-resistant *Staphylococcus aureus* screening criteria.

Two years is a limited amount of time to assess temporal trends, and rates of CAUTIs and HAIs in general should continue to be monitored to assess further trends. Additionally, although no prevention collaboratives in Pennsylvania targeted CAUTIs during the study period, some individual facilities might have employed other efforts to reduce CAUTIs. Such efforts would likely include focusing on reducing the number of days a patient has a urinary catheter in place, since this was designated a benchmark infection for public reporting. These types of efforts were not captured in our data; however, the inclusion of DURs attempts to control for differences in urinary catheter use over time and between locations. Other facility-specific confounders were included in the final model to control for inherent differences in the facilities. However, there might be other patient-specific risk factors not accounted for in this analysis that might have an effect on infection rates. The focus on the change in rates over time, comparing a group of facilities against itself, minimizes the impact of the differences between groups.

Another limitation of this study was that the validity of the qualitative responses to the survey questions, such as time spent on data tasks, was not evaluated. While the overall response rate was fairly high, response rates to some of the individual survey questions were low. Additionally, internal validation was performed on all of the data, but external validation is an ongoing process that Pennsylvania initiated in the fall of 2010. Facilities in Pennsylvania also utilize QES systems from a variety of vendors; the limited number of facilities using systems from the same vendor precluded any stratified analysis by vendor. There may be differences in performance by system vendor that we were unable to evaluate in this analysis. This data analysis was also performed with a limited selection of hospitals. Hospitals not included in the analysis were similar to facilities with a manual system in terms of bed size distribution and medical school affiliation but were similar to facilities with a QES system in terms of urban status. These results cannot be generalized to all facilities in Pennsylvania or to facilities in other states, nor can these results necessarily be generalized to other types of HAIs.

In summary, despite limitations due to the type of data collected, analysis of Pennsylvania's CAUTI data over a 2-year period demonstrated that facilities with a QES system experienced faster declines in infection rates than facilities with manual surveillance. This finding supports the potential benefit of moving toward automated electronic data collection and reporting. Widespread use of such systems could help make data more reliable and free the time of IPs to allow them to perform critical duties, including staff education and implementation of improved prevention practices. The requirements for reporting HAIs in Pennsylvania are extensive, and a QES system can help streamline the process of meeting those requirements. As public reporting becomes more widespread, facilities and organizations should recognize the benefits that may result from the adoption of electronic systems.[10]

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