ORIGINAL ARTICLE

Impact of Electronic Surveillance on Isolation Practices

Elaine Larson, RN, PhD, CIC, FAAN;[1,a] Maryam Behta, PharmD;[2,a] Bevin Cohen, MPH;[1] Haomiao Jia, PhD;[1] E. Yoko Furuya, MD, MS;[3] Barbara Ross, RN, BSN, CIC;[4] Rohit Chaudhry, MS;[5] David K. Vawdrey, PhD;[5] Katherine Ellingson, PhD[6]

OBJECTIVE. To assess the impact of an electronic surveillance system on isolation practices and rates of methicillin-resistant *Staphylococcus aureus* (MRSA).

DESIGN. A pre-post test intervention.

SETTING. Inpatient units (except psychiatry and labor and delivery) in 4 New York City hospitals.

PATIENTS. All patients for whom isolation precautions were indicated, May 2009–December 2011.

METHODS. Trained observers assessed isolation sign postings, availability of isolation carts, and staff use of personal protective equipment (PPE). Infection rates were obtained from the infection control department. Regression analyses were used to examine the association between the surveillance system, infection prevention practices, and MRSA infection rates.

RESULTS. A total of 54,159 isolation days and 7,628 staff opportunities for donning PPE were observed over a 31-month period. Odds of having an appropriate sign posted were significantly higher after intervention than before intervention (odds ratio [OR], 1.10 [95% confidence interval {CI}, 1.01–1.20]). Relative to baseline, postintervention sign posting improved significantly for airborne and droplet precautions but not for contact precautions. Sign posting improved for vancomycin-resistant enterococci (OR, 1.51 [95% CI, 1.23–1.86]; $P = .0001$), *Clostridium difficile* (OR, 1.59 [95% CI, 1.27–2.02]; $P = .00005$), and *Acinetobacter baumannii* (OR, 1.41 [95% CI, 1.21–1.64]; $P = .00001$) precautions but not for MRSA precautions (OR, 1.11 [95% CI, 0.89–1.39]; $P = .36$). Staff and visitor adherence to PPE remained low throughout the study but improved from 29.1% to 37.0% after the intervention (OR, 1.14 [95% CI, 1.01–1.29]). MRSA infection rates were not significantly different after the intervention.

CONCLUSIONS. An electronic surveillance system resulted in small but statistically significant improvements in isolation practices but no reductions in infection rates over the short term. Such innovations likely require considerable uptake time.

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Since the Study of the Efficacy of Nosocomial Infection Control in the 1970s,[1] surveillance has been recognized as an essential component of effective infection prevention and control programs. Manual data-collection methods, including clinical rounds and review of microbiologic and pharmacy reports, however, are time consuming and labor intensive and are subject to considerable interobserver variability, even with increasingly standardized definitions provided by the National Healthcare Safety Network. Furthermore, with traditional manual methods of data collection, it is difficult to link databases for rapid detection of healthcare-associated infections (HAIs) and assessment of patient risk factors and severity of illness. Recently, the potential for information linking and analysis has become more realistic, and automated systems offer the potential for monitoring and intervening much earlier than would be possible with manual data collection.[2,3] It appears, however, that most surveillance is still manual. Only 13% of infection preventionists (IPs) in a 2007 survey ($n = 150$) reported that they used such technology,[4] and 23% of infection prevention and control (IPC) departments in 2010 reported that they had an electronic surveillance system.[5] Despite the potential of automated systems for rapid linking and dissemination of data, the current status of automated HAI surveillance systems is not well described.

The aim of this study was to assess the impact of implementation of an automated surveillance system designed to rapidly identify patients who required isolation precautions and communicate that information to the IPC department and clinical staff to aid in decision making. The primary outcomes were adherence to guidelines for isolation precautions and rates of hospital-onset methicillin-resistant *Staphylococcus aureus* (MRSA).

Affiliations: 1. Columbia University School of Nursing, New York, New York; 2. University of Pennsylvania Health System, Philadelphia, Pennsylvania; 3. Columbia University College of Physicians and Surgeons, New York, New York; 4. NewYork-Presbyterian Hospital, New York, New York; 5. Columbia University Department of Biomedical Informatics, New York, New York; 6. Centers for Disease Control and Prevention, Atlanta, Georgia.

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TABLE 1. Description of Study Phases for Implementation of Electronic Surveillance System and Number of Observations during Each Phase

Phase	Description	Dates	No. of observations
I. Baseline	Direct observation of isolation practices; no interventions	May 2009–Dec 2009	10,139
II. Admitting screen	Isolation information for the most common organisms (eg, MRSA and VRE) automatically sent to admitting office	Jan 2010–Aug 2010	17,515
III. Provider order screen	Implemented a required field for ordering isolation at the time of admission; revised isolation orders to be searchable by isolation category and/or organism name and clinical indication; released isolation information to nursing patient care directors and charge nurses, admitting and unit clerks; captured clinical information within surveillance system (orders and flow sheet notes)	Sep 2010–Dec 2010	10,075
IV. Clinician/unit staff screen	Initiate information tab within the patient record to provide a new method to share isolation information; infection prevention liaisons conducted huddles with staff to review isolation policies, protective attire; education/staff notification of the new feature	Jan 2011–Jun 2011	16,430

NOTE. MRSA, methicillin-resistant Staphylococcus aureus; VRE, vancomycin-resistant enterococci.

METHODS

Sample and Setting

The study was conducted in 4 hospitals that comprised a large healthcare system in New York City: a 221-bed community hospital, a 283-bed free-standing pediatric acute care facility, a 647-bed adult academic tertiary care facility, and a 914-bed pediatric/adult academic tertiary care facility. All inpatient units, with the exception of psychiatric and maternity wards, were included.

Initial Development and Testing of Automated Surveillance System

In 2002, the institution's IPC and information technology departments collaborated with the Columbia University Department of Biomedical Informatics to develop an automated surveillance system that used existing hospital and University information systems. A web-based microbiology surveillance application was developed that used data extracted from the institution's clinical data warehouse. The details of the hardware and software infrastructure have been previously described.[6,7] The system was accessible from any hospital computer or via secure remote access. It included modules to support activities of the IPs, such as identifying patients with bloodstream and urinary tract infections, and monitoring of organism-specific incidence and prevalence rates. Two laboratories provide data to the system, and all laboratory data are processed through a single medical entity dictionary.

The system aggregates information at the patient level with built-in rules and logic derived from Centers for Disease Control and Prevention guidelines for the type and source of the confirmed or suspected organism. The system is primarily driven by past or current positive microbiological culture results and/or clinician isolation orders based on clinical indications and symptoms. The IPs perform "virtual rounds" throughout the day to identify those patients who were placed under isolation precautions after the IPs physically performed rounds on the units. Finally, the system identifies patients with a known history of multidrug-resistant organisms and other organisms of interest upon readmission and includes a method to discontinue isolation when specified criteria are met. The isolation module generates a twice-daily list of patients who require isolation at admission or who have any relevant positive microbiological culture result.

Study Phases and Design

As summarized in Table 1, the study was conducted in 4 phases. In phase I, baseline data were collected using the existing process of the IPC department for 3 months. The IPs then relayed the information to the admitting department and/or the medical teams via telephone or during rounds.

In phase II, a new screen was built within the admitting system to display the details of the organism name, most recent source, most recent date of a positive culture result, and personal protective equipment (PPE) requirements. Information entered or approved by the IPs in the isolation module was automatically transmitted to the admitting system, which eliminated the need for a manual notification by an IP. The system was also enhanced so that the isolation information for selected organisms (eg, MRSA, vancomycin-resistant enterococci [VRE], and *Clostridium difficile*) was automatically processed by the surveillance system. This allowed new isolation information to be processed during nights and

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TABLE 2. Frequency of Appropriate Sign Posting, Equipment Availability, and Staff and Visitor Adherence to Precautions

Practice	Baseline (reference)	Admission screen	Provider order screen	Clinical staff screen	All post-intervention phases
Isolation sign posted[a]					
Percentage	91.8	92.0	92.2	**93.1**	**92.4**
Numerator/denominator	7,295/7,950	13,808/15,010	7,784/8,447	**12,877/13,835**	**34,469/37,292**
OR (95% CI)	...	...	...	**1.21 (1.09–1.34)**	**1.10 (1.003–1.200)**
Isolation cart present[a]					
Percentage	94.1	94.7	92.8	93.3	93.7
Numerator/denominator	6,602/7,015	12,615/13,322	6,997/7,537	11,576/12,413	31,188/33,272
OR (95% CI)	...	...	...	...	...
Gloves available[a]					
Percentage	94.9	**95.9**	94.5	95.0	95.3
Numerator/denominator	7,544/7,950	**14,397/15,010**	7,984/8,447	13,142/13,833	35,523/37,290
OR (95% CI)	...	**1.26 (1.11–1.44)**	...	...	...
Appropriate donning of PPE[b]					
Percentage	29.1	28.4	**33.1**	**37.0**	**31.8**
Numerator/denominator	456/1,568	765/2,693	**520/1,573**	**644/1,794**	**1,929/6,060**
OR (95% CI)	...	...	**1.20 (1.04–1.40)**	**1.37 (1.18–1.58)**	**1.14 (1.01/1.29)**

NOTE. Data are percentage and proportion of correct practices at each phase and for all postintervention phases and OR (95% CI) for statistically significant improvement compared with baseline. CI, confidence interval; OR, odds ratio; PPE, personal protective equipment. Boldface type indicates statistically significant improvement over baseline.

[a] For isolation-days identified through the electronic surveillance system.

[b] For patients with an isolation sign posted at the time of observation.

on the weekends and for clinical teams to receive the information faster when the epidemiology team was not on site.

In phase III, the provider orders for isolation precautions were revised to make it easier to order isolation precautions. The orders were also standardized throughout the 4 hospitals involved in the study. In phase IV, all members of patient care teams had access to a dedicated tab in the electronic health record (Sunrise Clinical Manager; Allscripts) that displayed detailed isolation precautions information for each patient. This new tab was used to view active and historical isolation information at the time of admission and handoff.

Data Collection Procedures and Quality Monitoring

Approval was obtained from the institutional review boards of the study institutions. Data were collected between May 2009 and June 2011. Five observers were trained to assess adherence to isolation precautions. As described previously,[6,8] observer training included careful review of the observation protocols and ongoing interrater reliability assessments with research staff who had conducted similar observations in previous studies. Direct observations of rooms that housed isolated patients were performed in 5-consecutive-day increments (including weekends) during varying times of the day (5 AM to 12 AM) at each of the study sites. Observers were instructed not to intervene if they witnessed noncompliance with isolation protocols. The team met weekly throughout the study to resolve problems, clarify emerging issues, and assure consistency of definitions and methods across data collectors and sites. The observation methods were monitored for ongoing consistency and reliability by study investigators.

Each observer recorded data on the appropriateness of isolation sign postings (ie, whether the correct sign was posted, as indicated by the infected site and organism that necessitated the isolation); the availability of an isolation cart supplying personal protective equipment (PPE), including gloves, gowns, and masks; and whether individuals entering or leaving the room adhered to the recommended isolation protocols. As described previously, data were recorded during observation directly into an electronic form using tablet computers.[6]

Data Management and Analysis

The data were cleaned, and the indications for isolation at the time of each observation were verified. The unit of analysis was the number of observations (not individual patients). The following were compared between each study phase: the proportion of observed isolation days during which an isolation sign was posted at the patient's door; availability of an isolation cart and appropriate PPE outside the patient's room; rates of staff and visitor adherence to appropriately donning PPE upon entering an isolated patient's room; and incidence density of MRSA infection, because it was the most common indication for isolation in the study institutions. Logistic regression models were used to examine the odds of appropriate signage, isolation cart availability, and adherence to appropriate donning of PPE for all study phases combined compared with baseline.

Hospital-onset incidence densities were calculated for the initial isolates of MRSA obtained from a patient more than 72 hours after admission. Generalized estimating equation

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TABLE 3. Percentage with Correct Isolation Sign by Type of Isolation and Organism

Correct sign	Baseline (reference), %	Admission screen %	Admission screen OR (95% CI)	Provider order screen %	Provider order screen OR (95% CI)	Clinical staff screen %	Clinical staff screen OR (95% CI)
By isolation category							
Contact (n = 37,540)	92.7	93.4	...	92.6	...	**95.0**	**1.52 (1.30–1.76)**
Droplet (n = 5,482)	86.4	88.5	...	83.2	...	82.5	
Airborne (n = 1,176)	84.9	87.1	...	**91.0**	**1.81 (1.01–3.22)**	**93.0**	**2.37 (1.22–4.59)**
By organism[a]							
VRE (n =15,707)	95.7	**96.9**	**1.37 (1.03–1.82)**	**98.0**	**2.18 (1.57–3.03)**	**97.5**	**1.73 (1.25–2.40)**
MRSA (n =13,291)	96.1	96.8	...	96.8	...	**97.4**	**1.50 (1.05–2.16)**
Clostridium difficile (n = 7,576)	90.7	**94.1**	**1.65 (1.22–2.23)**	**94.1**	**1.65 (1.20–2.26)**	**94.8**	**1.87 (1.33–2.63)**
Klebsiella pneumoniae (n = 5,091)	96.2	97.4	...	**98.1**	**1.98 (1.09–3.57)**	97.4	...
Other gram-negative organisms (n = 4,559)	88.3	**96.5**	**3.68 (2.31–5.86)**	**95**	**2.48 (1.68–3.66)**	**95.7**	**2.92 (1.87–4.57)**
Pseudomonas aeruginosa (n = 4,635)	95.1	95.2	...	95.2	...	97	...
Acinetobacter baumannii (n = 3,608)	94	95.1	...	93.7	...	93.2	...
Mycobacterium tuberculosis (n = 1,318)	84.9	87.1	...	**91.0**	**1.81 (1.01–3.22)**	**95.2**	**3.49 (1.58–7.71)**
Varicella zoster virus (n = 358)	70.6	83.6	...	**86.2**	**2.59 (1.03–6.55)**	85.7	...

NOTE. CI, confidence interval; MRSA, methicillin-resistant *Staphylococcus aureus*; OR, odds ratio; VRE, vancomycin-resistant enterococci. Boldface type indicates statistically significant improvement over baseline.

[a] The n value is no. of observations.

negative binomial regression models were used to examine changes in incidence density before and after the implementation of each phase of the study, incorporating a correlated variance structure of patients nested within clinical units.

RESULTS

A total of 54,159 isolation days (10,252 patients) were observed over the 4 study phases (Table 1): 54.6% from the adult/pediatric academic tertiary care hospital, 28.2% from the adult academic tertiary care hospital, 11.1% from the children's hospital, and 6.1% from the community hospital. Additionally, 7,628 episodes were observed of individuals donning PPE before entry into a room housing an isolated patient. The majority (45,242; 83.5%) of the patients observed were identified through the electronic surveillance system, and the remainder (8,917; 16.5%) had isolation initiated by the staff on the nursing unit on the basis of clinical signs and symptoms. During the baseline and all phases of the study, an isolation sign was posted, and an isolation cart and gloves were available outside the patient's room on more than 90% of the isolation days. The odds ratios (OR) of having an appropriate sign posted and an isolation cart and gloves at the door, comparing all study phases with baseline, were not significant. Adherence to donning appropriate PPE was low at baseline (29.1%) and throughout all phases of the study. Although it improved in several study phases and was significantly higher across all intervention phases when compared with baseline, the absolute changes were minimal (Table 2).

Sign posting was significantly improved for airborne and contact precautions, but not for droplet precautions (Table 3). Vancomycin-resistant enterococci (22.0%), MRSA (18.6%), and *C. difficile* (10.6%) represented the largest proportions of organisms associated with need for isolation; all other organisms each represented less than 10% of the total. Appropriate sign posting was significantly improved for VRE and *C. difficile*, but not for MRSA. There were no significant reductions in MRSA rates associated with any of the study phases (Table 4).

DISCUSSION

Although automated alerts to control transmission of multidrug-resistant organisms have been suggested for over a decade, there are considerably fewer studies assessing the results of such applications. Almost a decade ago, Pittet et al[9] used computer-generated reports to alert IPC staff when a patient with MRSA infection was admitted to the hospital. The infection control staff then contacted the physician. Although this intervention was associated with a reduction in the time to obtain follow-up cultures and an increase in the proportion of patients with MRSA infection who were identified at admission, it was resource intensive and time consuming.[9] In a systematic literature review of randomized and nonrandomized controlled trials to evaluate the effects of computerized clinical decision support systems, Garg et al[10] found positive changes in provider behavior in approximately two-thirds of studies (16 of 21 studies) that used reminder systems. Improved performance was associated with systems that used automatic prompts compared with prompts that required user activation; there was success in 73% and 47% of trials, respectively (P = .02). A French research team in a 750-bed teaching hospital reported the use of an electronic system to provide staff alerts regarding the need for isolation precautions among patients with drug-resistant infections.[11]

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TABLE 4. Incidence Density of Methicillin-Resistant *Staphylococcus aureus* by Study Phase and Hospital

Phase	Incidence density per 1,000 patient-days (95% confidence limits)	Relative risk[a] (95% confidence limits)
I. Baseline	0.64 (0.46–0.89)	1.00 (reference)
II. Admission screen	0.69 (0.55–0.87)	1.08 (0.81–1.44)
III. Provider order screen	0.74 (0.57–0.95)	1.15 (0.83–1.61)
IV. Clinician/unit staff screen	0.65 (0.52–0.82)	1.02 (0.77–1.36)

[a] Generalized estimating equation negative binomial models to incorporate correlated variance structure that patients were nested within clinical units.

When alerts were sent to members of the infection control team, who then ordered isolation precautions on electronic nursing records, awareness of the infected status among the nursing staff increased from 24.0% at baseline to 93.1% after 1 year, and implementation of isolation precautions increased from 15.0% to 90.2%. Significant improvements were sustained over the several years of the study. Kho et al[12] evaluated a computerized physician reminder for contact precautions for patients with multiply drug-resistant infections and demonstrated significant improvements in compliance but no changes in rates of HAI.

The overall goal of our study was to determine the impact of an automated surveillance system on the implementation of isolation precautions and rates of MRSA. Although there were several statistically significant changes in rates of appropriate sign posting and use of PPE, the changes were small and not likely to be of great clinical significance. We do not know why there were significant differences in signage by organism; perhaps it was a chance finding, or it is possible that some organisms elicit more concern among staff than others and that staff are therefore more likely to put up a sign when such organisms are involved. Perhaps the most important advantage of this system, therefore, was the time savings for staff. As noted in Ross et al,[6] the system saved approximately 1,300 hours per year in case finding, review of cases, and documentation. This was probably an underestimate, because there was no way to take into account the duplicate evaluations that may have occurred as the result of a manual, error-prone process.

Clearly, simple processes are necessary for early identification of patients who require isolation, communication of the PPE needed, and continuous monitoring of adherence to precautions. Behavioral changes and alteration of staff members' habits, on the other hand, likely require additional time. Although changes across the 4 study phases were small, there were statistically significant improvements in several outcomes, including having the appropriate isolation sign posted and staff and visitor adherence to donning PPE. We postulate that, when staff on the clinical units are directly alerted to the need for patient isolation, rather than depending upon the IPC department to inform them, they will be more likely to develop a sense of ownership about infection prevention practices, and continued improvements will ensue over time as clinicians increasingly take advantage of the additional information regarding indications for patient isolation now available to them electronically.

As with many behavioral changes, the initial "uptake" has taken some time. During the first 3 months of the final phase of the study, the isolation module of the clinician screen was visited 23,024 times; during the same 3 months a year later, the tab was viewed 61,518 times, a 2.7-fold increase. We anticipate that there will be continued improvement in adherence as staff members incorporate the infection and isolation alerts into their practice.

Study Limitations

As with all quasi-experimental designs with longitudinal data collection, we cannot rule out the potential impact of other temporal changes occurring during the same time period. There were also technical problems and delays that may have discouraged staff from using the system. The surveillance system was designed in house, and it is likely that the system is not always correct. It did represent, however, the most complete database available in the study sites. It is also likely that the presence of observers may have induced a Hawthorne effect, but that would have been present throughout every phase of the study. Although some of our findings were statistically significant because of large sample sizes, the clinical significance may be limited for certain outcomes. Finally, the reasons for any improvement in compliance with isolation practices will be multifactorial, and behavioral changes, such as increased adherence to precautions, often require considerable time to occur. The duration of our study period may have been insufficient to capture long-term changes.

Conclusions

Decision support technology resulted in small but statistically significant changes in appropriate implementation of isolation practices; despite these marginal improvements, adherence was still unacceptably low, which suggests that technological improvements should be coupled with other longer-term interventions to promote behavioral change. The potential efficiencies and cost savings to the IPC program

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associated with electronic surveillance technology are considerable, as we have previously reported,[6] and will allow epidemiology staff to focus on important responsibilities other than surveillance, such as education, follow-up, and planning and implementation of interventions for improvement.

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Address correspondence to Elaine Larson, PhD, Columbia University School of Nursing, 630 West 168th Street, New York, NY 10032 (ell23@columbia.edu).

[a] These authors contributed equally to the conduct of this study and the preparation of the manuscript.

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