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## ORIGINAL ARTICLE

# Electronic Surveillance for Healthcare-Associated Central Line-Associated Bloodstream Infections Outside the Intensive Care Unit

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**BACKGROUND.** Manual surveillance for central line-associated bloodstream infections (CLABSIs) by infection prevention practitioners is time-consuming and often limited to intensive care units (ICUs). An automated surveillance system using existing databases with patient-level variables and microbiology data was investigated.

**METHODS.** Patients with a positive blood culture in 4 non-ICU wards at Barnes-Jewish Hospital between July 1, 2005, and December 31, 2006, were evaluated. CLABSI determination for these patients was made via 2 sources; a manual chart review and an automated review from electronically available data. Agreement between these 2 sources was used to develop the best-fit electronic algorithm that used a set of rules to identify a CLABSI. Sensitivity, specificity, predictive values, and Pearson's correlation were calculated for the various rule sets, using manual chart review as the reference standard.

**RESULTS.** During the study period, 391 positive blood cultures from 331 patients were evaluated. Eighty-five (22%) of these were confirmed to be CLABSI by manual chart review. The best-fit model included presence of a catheter, blood culture positive for known pathogen or blood culture with a common skin contaminant confirmed by a second positive culture and the presence of fever, and no positive cultures with the same organism from another sterile site. The best-performing rule set had an overall sensitivity of 95.2%, specificity of 97.5%, positive predictive value of 90%, and negative predictive value of 99.2% compared with intensive manual surveillance.

**CONCLUSIONS.** Although CLABSIs were slightly overpredicted by electronic surveillance compared with manual chart review, the method offers the possibility of performing acceptably good surveillance in areas where resources do not allow for traditional manual surveillance.

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Surveillance for healthcare-associated infections has long been recognized as a vital component of effective infection prevention programs.<sup>1</sup> Standardized surveillance has clearly aided the steady reduction of central line-associated bloodstream infection (CLABSI) rates in intensive care unit (ICU) patients by allowing the impact of infection prevention efforts to be measured.<sup>2</sup> However, using the definitions of the Centers for Disease Control and Prevention's National Healthcare Surveillance Network (NHSN) is very labor intensive and time-consuming. For this reason, CLABSI surveillance efforts are often limited to ICUs, which represent a fairly well-defined patient population with historically relatively high central line use. In addition, there has been an implicit assumption that ICU patients are at higher risk for CLABSI. However, a number of studies have indicated that non-ICU patients have an equally high risk of CLABSI.<sup>3,4</sup> Furthermore, in many hospitals there may actually be more patients with

catheters outside the ICU than in it.<sup>5</sup> The lower utilization rates of central lines outside the ICU and the larger, more widely distributed population exacerbate the effort required for adequate surveillance of CLABSI by means of the traditional manual methods. The increasing availability of patient and laboratory data offer the potential for automating the process. A preliminary study suggested that this approach was feasible, but the study was hampered by the lack of an electronic source of central line data.<sup>6</sup> We report here a pilot project to evaluate totally electronic surveillance of CLABSI.

## METHODS

### Study Population

Barnes-Jewish Hospital is a 1,250-bed tertiary care teaching hospital affiliated with Washington University School of Medicine in St. Louis, Missouri. Two general medical wards and

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TABLE 1. Performance of Individual Rules and Aggregate Rule Sets

	No. of BSIs confirmed by rule set	Sensitivity, %	Specificity, %	PPV, %	NPV, %	$\kappa$	Pearson's correlation
Rule 1: hospital acquired	239	100 (95.7–100)	57.9 (52.8–62.9)	35.6 (29.8–41.8)	100 (98.2–100)	.342	.454
Rule 2a: non-CSC	238	100 (95.7–100)	58.2 (53.1–63.1)	35.7 (29.9–42.0)	100 (98.2–100)	.344	.456
Rule 2b: non-CSC (with fever)	210	100 (95.7–100)	65.8 (60.9–70.5)	40.5 (34.1–47.2)	100 (98.4–100)	.421	.516
Rule 3: CVC	229	95.3 (88.5–98.2)	59.5 (54.5–64.5)	35.4 (29.5–41.8)	98.2 (95.5–99.3)	.389	.492
Rule 4a: no secondary BSI	396	91.7 (84.0–96.0)	13.1 (10.0–17.0)	19.7 (16.1–23.9)	87.3 (76.0–93.7)	.020	.058
Rule 4b: no secondary BSI (before only)	433	98.8 (93.6–99.8)	4.6 (2.9–7.3)	19.4 (16.0–23.4)	94.4 (74.2–99.0)	.013	.069
Rule set 1, 2b, 3, 4a	80	87.1 (78.3–92.6)	98.4 (96.5–99.3)	92.5 (84.6–96.5)	97.0 (94.8–98.3)	.874	.875
<b>Rule set 1, 2b, 3, 4b</b>	<b>90</b>	<b>95.2 (88.5–98.2)</b>	<b>97.5 (95.4–98.7)</b>	<b>90.0 (82.1–94.7)</b>	<b>99.2 (97.2–99.6)</b>	<b>.908</b>	<b>.908</b>
Rule set 1, 2, 3, 4	92	87.1 (78.3–92.6)	95.1 (92.4–96.9)	80.4 (71.2–87.3)	96.9 (94.6–98.3)	.796	.797
Rule set 1, 2a, 3, 4b	101	94.1 (87.0–97.5)	94.3 (91.4–96.2)	79.2 (70.3–86.0)	98.6 (96.7–99.4)	.824	.829
Rule set 1, 2a, 3, 4c	85	91.8 (84.0–95.6)	98.1 (96.1–99.1)	91.8 (84.0–96.0)	98.1 (96.1–99.1)	.899	.899
Rule set 1, 2a, 3, 4d	86	91.8 (84.0–96.0)	97.8 (95.8–98.9)	90.7 (82.7–95.2)	98.1 (96.1–99.1)	.892	.892

NOTE. Data in parentheses are 95% confidence intervals. Boldface type indicates the best-fit rule set. BSI, bloodstream infection; CSC, common skin contaminant; CVC, central venous catheter; NPV, negative predictive value; PPV, positive predictive value.

2 general surgical wards were chosen for surveillance. These units were selected to provide a variety of patient types, and the anticipated patient volumes were within our ability to conduct manual surveillance (routine surveillance by hospital infection prevention was not in place in these units). All patients on the surveillance wards with a positive blood culture between July 1, 2005, and December 31, 2006, were included in the study. Human studies committee approval for the project was obtained before initiation.

### Manual Surveillance

Patients who had a positive blood culture were identified from the hospital informatics database.<sup>7,8</sup> The charts of these patients were reviewed using a standardized data collection tool, and data were entered into an SPSS data set. The data were reviewed with a hospital epidemiologist to confirm a CLABSI using the NHSN definitions current at the time. After the initial data abstraction, NHSN criteria for CLABSI changed—specifically, patients with a single culture positive for a common skin contaminant who received antimicrobial therapy no longer met the definition for a CLABSI.<sup>9,10</sup> Our manually collected data set had sufficient information to allow reclassification of patients who no longer met the revised NHSN definition.

### Electronic Surveillance

Patients on the surveillance wards with positive blood cultures were identified from the hospital informatics database. Non-organism concepts (eg, *Aspergillus* galactomannan) that were reported to the database as “positive cultures” were filtered from the data set before analysis. Additional electronically available data (eg, positive cultures from other sites, laboratory values, patient temperature, and presence of a central line) were pulled by standardized query into an analysis data set. A series of yes/no electronic rules applicable to the determination of CLABSI were applied (similar to rules reported

by Trick et al<sup>6</sup>). These rules were then applied in different combinations to determine which set of rules most closely matched the CLABSI determination from the manual surveillance. The individual rules are as follows:

1. Hospital acquired: positive blood culture was obtained 48 hours or more after hospital admission.
2. Non-common skin contaminant:
  - a. Culture positive for non-common skin contaminant pathogen or culture positive for common skin contaminant<sup>9</sup> that was confirmed with another positive culture of the same organism within 3 days.
  - b. Culture positive for non-common skin contaminant pathogen or culture positive for common skin contaminant<sup>9</sup> that was confirmed with another positive culture of the same organism within 3 days and the patient had a fever (temperature more than 38.0°C within 48 hours of the blood culture).
3. Central venous catheter: patient had a central venous catheter in place at the time of culture or discontinued within 48 hours before culture.
4. No secondary bloodstream infection: no positive culture of the same organism from any other body site (many combinations were evaluated, and a selected few are shown below).
  - a. Anytime during the admission.
  - b. Anytime during the admission before the blood culture date.
  - c. Anytime during the admission before or within 7 days after the blood culture date.
  - d. Anytime during the admission within 14 days before or 7 days after the blood culture date.

Any other positive blood culture within 7 days of the CLABSI culture was assumed to be part of the same infection and so was not counted as a new infection. Any positive

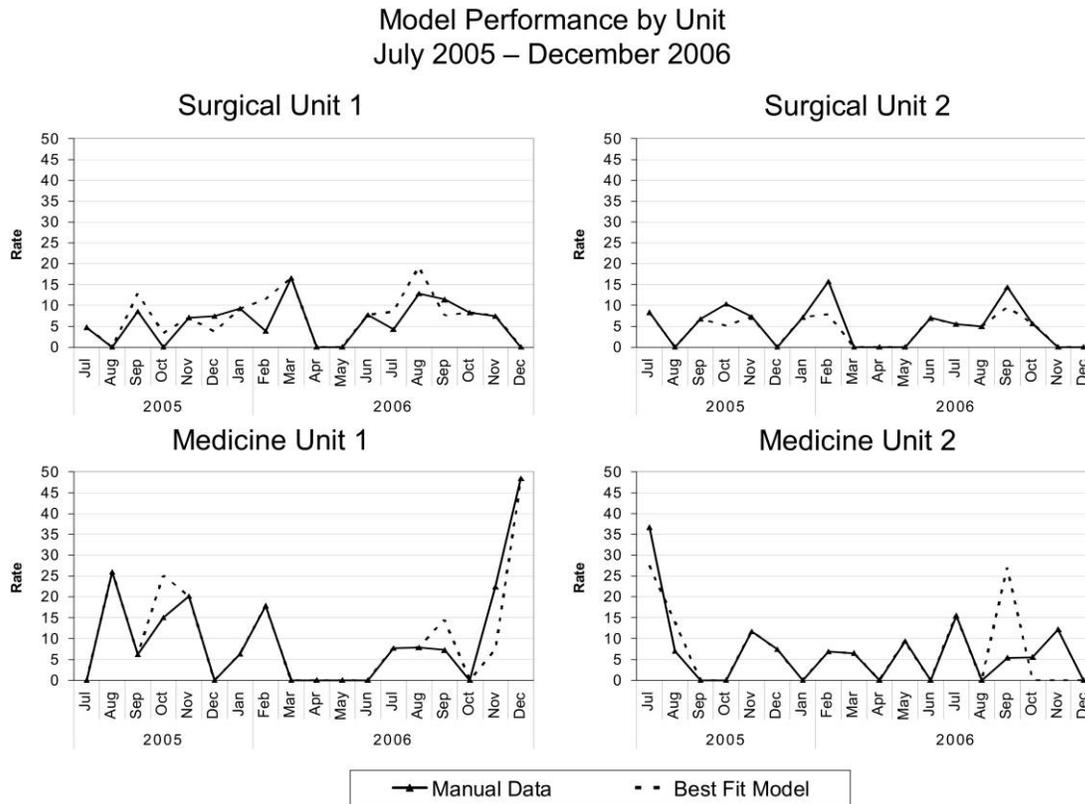


FIGURE 1. Comparison of unit-level central line-associated bloodstream infection rates (cases per 1,000 central line-days) over time.

culture with the same organism as the CLABSI culture within 14 days of the initial culture was also assumed to be part of the same CLABSI.

Sensitivity, specificity, predictive values, and Pearson's correlation were calculated for the various new rule sets, using manual chart review as the reference standard. For the best-fit model,  $\chi^2$  analysis was completed comparing the manual and electronic CLABSI rates.

## RESULTS

During the study period, 391 positive blood cultures from 331 patients were evaluated. Eighty-five (22%) of these were confirmed to be CLABSI by manual chart review. Individual rules, not unexpectedly, performed relatively poorly. The best-fit model, which included rules 1, 2b, 3, and 4b, predicted 90 CLABSIs (23%; Table 1). The CLABSI rate by manual surveillance was 6.37 cases per 1,000 central line-days (95% confidence interval, 5.0–7.7) versus 6.75 cases per 1,000 central line-days (95% confidence interval, 5.4–8.1;  $P = .76$ ).

CLABSIs remain slightly overpredicted compared with manual chart review. Preliminary analyses of the original data set (before the change in NHSN criteria; data not shown) evaluated specific sites (eg, wounds and urine) alone and in a variety of combinations, but they did not result in improvement over using all culture sites to eliminate potential

secondary bloodstream infections; these analyses were not repeated with the updated data set. Likewise, analyses of the initial data set evaluating the utility of incorporating the patient's white blood cell count did not yield improved performance and so were not repeated in this set of analyses.

In addition to overall performance, the performance of the best-fit model on a month-to-month basis for each ward was determined (Figure 1). While electronic surveillance tended to predict higher CLABSI rates than manual surveillance, overall the trend lines were comparable. In ward 1, the number of cases from manual surveillance was 26, whereas electronic surveillance found 33; in ward 2, 13 and 12 cases were found, respectively; in ward 3, 26 and 27 cases were found, respectively; and in ward 4, 20 and 18 cases were found, respectively ( $P > .5$  for the comparison of manual to electronic CLABSI rates for each individual ward).

## DISCUSSION

A variety of studies have proposed electronic methods of surveillance for bloodstream infections in general.<sup>11–14</sup> However, most institutions have focused on CLABSIs, because these seem more amenable to prevention interventions. The study by Trick et al<sup>6</sup> provided a solid step toward performing automated surveillance for CLABSI, but those investigators did not have access to central line data electronically. Our

current study shows results comparable to, if not slightly better than, those of Trick and colleagues and has the advantage that surveillance could be done completely electronically. One potential weakness of our current study is that after developing the rules we did not validate them on a separate set of patients. As noted below, we are in the process of implementing these rules in multiple hospitals, which will allow for additional validation.

Our electronic surveillance has overall higher rates than manual surveillance. At least some of the infections that were identified electronically were likely secondary infections that did not have a site culture that met our electronic criteria (data not shown). Conversely, we may be eliminating true CLABSIs if the same organism from another site does not represent a true secondary infection (eg, *Candida* in a sputum sample). While this may argue for including some element of human review, there may be advantages to a completely objective surveillance method. A steady body of literature has indicated the existence of significant interrater variation in determining the presence of healthcare-associated infections.<sup>15-17</sup> There is no evidence to suggest that interrater reliability improves with years of experience, and even within institutions there appears to be significant interobserver variations in determining whether a patient has a CLABSI.<sup>18</sup> This variability, combined with less comprehensive case finding, tends to lead toward underreporting of CLABSI by traditional surveillance.<sup>6,19-21</sup> Thus, while electronic surveillance may report a higher rate than traditional surveillance, the “true rate” is probably somewhere in between. Since we did not have traditional manual surveillance in place in the study units, we were not able to validate this assumption as part of our study. However, a pilot validation study comparing our algorithm with traditional surveillance rates in our ICUs did find that the “validated rates” were between the electronic rates and the rates reported by infection control (data not shown).

Fully automated electronic surveillance for CLABSI outside the ICU offers the potential for performing whole-house CLABSI surveillance without requiring a dramatic increase in resources. This extended scope may help hospitals comply with regulatory requirements for performing surveillance for CLABSI, such as the Joint Commission’s National Patient Safety Goals. Because this method uses different definitions than traditional surveillance, healthcare personnel should not try to compare the electronic rates with NHSN rates. In particular, electronic surveillance rates will include unconfirmed secondary bloodstream infections, and “zero” rates cannot be expected. Nevertheless, we believe that electronic surveillance can provide valuable insight into areas of the hospital with better or worse CLABSI performance to help us target our improvement interventions. The electronic surveillance will also show the impact of such interventions. To assist in the acceptance of fully automated surveillance in non-ICU areas, we have decided to use a term other than “CLABSI rates” so as not to confuse them with NHSN-type rates. We

are using the term “NICER,” for non-ICU CLABSI electronic rates. Currently, we are in the process of implementing NICER surveillance at all BJC HealthCare facilities.

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