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Major articles

Performance characteristics and associated outcomes for an automated surveillance tool for bloodstream infection

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Background: The objective of this study was to evaluate performance metrics and associated patient outcomes of an automated surveillance system, the blood Nosocomial Infection Marker (NIM).
Methods: We reviewed records of 237 patients with and 36,927 patients without blood NIM using the National Healthcare Safety Network (NHSN) definition for laboratory-confirmed bloodstream infection (BSI) as the gold standard. We matched cases with noncases by propensity score and estimated attributable mortality and cost of NHSN-reportable central line–associated bloodstream infections (CLABSIs) and non–NHSN-reportable BSIs.
Results: For patients with central lines (CL), the blood NIM had 73.2% positive predictive value (PPV), 99.9% negative predictive value (NPV), 89.2% sensitivity, and 99.7% specificity. For all patients regardless of CL status, the blood NIM had 53.6% PPV, 99.9% NPV, 84.0% sensitivity, and 99.9% specificity. For CLABSI cases compared with noncases, mortality was 17.5% versus 9.4% ($P = .098$), and median charge was $143,935 (interquartile range [IQR], $89,794-$257,447) versus $115,267 (IQR, $74,937-$173,053) ($P < .01$). For non–NHSN-reportable BSI cases compared with noncases, mortality was 23.6% versus 6.7% ($P < .0001$), and median charge was $86,927 (IQR, $54,728-$156,669) versus $62,929 (IQR, $36,743-$115,693) ($P < .0001$).
Conclusions: The NIM is an effective screening tool for BSI. Both NHSN-reportable and nonreportable BSI cases were associated with increased mortality and cost.

BACKGROUND

Surveillance for health care–associated infections (HAIs), including central line–associated bloodstream infections (CLABSIs), is a crucial component of any hospital infection control program. Not only is CLABSI surveillance important for tracking quality of care and patient safety, but reporting of CLABSI rates to the National Healthcare Safety Network (NHSN) is legally required in 31 U.S. states and by the Centers for Medicare and Medicaid Services (CMS).[1,2]

However, CLABSI surveillance can be both labor-intensive and time-consuming. Most hospitals rely on infection preventionists to manually perform CLABSI monitoring via medical record review, applying case definitions determined by the NHSN.[3] Because of limited resources and legal requirements and CMS reimbursement considerations, many hospital infection control programs focus primarily on surveillance of HAIs that are required to be reported to the NHSN, such as CLABSI, at the expense of time spent on other important surveillance and infection control activities.[4] Surveillance for other HAIs besides those that meet narrow NHSN definitions is important because these other HAIs may also lead to poor patient outcomes and increased costs of hospitalization. Reducing the amount of time and effort required to perform CLABSI surveillance would allow infection control programs to engage in surveillance for other HAIs that do not meet NHSN criteria and other infection prevention efforts.

In the era of widespread electronic health records, an automated surveillance tool could decrease the manual effort involved

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in screening patients for CLABSI and other HAIs.[5,6] CareFusion's MedMined (San Diego, CA) is one such automated surveillance tool that flags potential HAIs via the Nosocomial Infection marker (NIM).[7] NIMs are determined via a proprietary automated algorithm that includes patients' admission, discharge, and transfer data, census data, and microbiology data and excludes duplicate results and cultures that likely represent contamination.

The NIM tool can be used to screen for CLABSI and other HAIs, but its performance characteristics for detecting bloodstream infections (BSIs) and associated outcomes have not been studied in depth. Two prior studies evaluating the NIM for detection of BSI compared with medical record review found its sensitivity to be 78%-100%, but these studies were small (1 study only included 7 BSI cases) and did not evaluate patient outcomes.[7,8] We elected to undertake a larger, more rigorous evaluation of the NIM for detection of BSI and to investigate the association of the blood NIM with patient outcomes.

This study aims to (1) determine the performance characteristics (positive predictive value [PPV], negative predictive value [NPV], sensitivity, specificity, and positive likelihood ratio [PLR]) of the blood NIM for detecting laboratory-confirmed bloodstream infection (LCBI), including CLABSI; and (2) determine the association of the blood NIM with outcomes of mortality, length of stay (LOS), and cost.

METHODS

Performance characteristics of blood NIM

To determine the performance characteristics of the blood NIM, we performed record review of all adult patients with blood NIMs from January 1, 2010-December 31, 2011, at the 4 hospitals within our health system. We compared blood NIM cases against a gold standard of the NHSN definition for LCBI in place at the time of the study (Table 1). We also reviewed the records of 36,927 control patients, a 33% random sample of all blood NIM–negative admissions during the study period. We extrapolated the results from these control patients to the entire blood NIM–negative patient population during the study period. These extrapolated numbers were used to determine sensitivity and specificity.

Patients who had positive blood cultures (and were therefore eligible for LCBI under the NHSN definition) underwent comprehensive chart review; patients without positive blood cultures were presumed to be negative for LCBI. Record review was performed by an infectious disease (ID) physician with training in hospital epidemiology and infection control. For patients with central lines in place, the hospitals' infection preventionists independently reviewed all positive blood cultures to determine if they met the NHSN definition of CLABSI.[3] Results of the record review by the ID physician were compared with the CLABSI cases as determined by the infection preventionists. Any discrepancies between the infection preventionists and the ID physician in determination of CLABSI were resolved by the director of infection control.

PPV was first calculated as the percentage of blood NIM cases that met the NHSN definition of LCBI regardless of central line status.[9] Then we re-estimated the PPV restricting the population to patients with qualified central lines (Table 1). Among blood NIM cases that did not meet the NHSN definition of LCBI, we further determined if they met criteria for another NHSN-defined infection (secondary BSI) or if they did not meet criteria for any NHSN-defined infection (eg, a single positive blood culture with an organism that is a common skin commensal).

Finally, we estimated the PLR, a metric to determine whether a positive test usefully augments the probability that disease is truly present. The PLR is calculated as sensitivity divided by (1 – specificity).

Association of blood NIM with outcomes

Patients' demographic, clinical, and outcome-related data were collected from our health system's data warehouse. We classified cases as NHSN-reportable BSI if they met criteria for CLABSI (line-associated primary LCBI), meaning that a health care organization would be required to report them to the NHSN. We classified cases as non–NHSN-reportable BSI if they met the criteria for an NHSN-defined infection[3] but were not required to be reported to the NHSN either because the BSI was secondary to another source or because the case was not associated with a qualified central line. Although these non–NHSN-reportable BSI cases can be reported to the NHSN on a voluntary basis, most health care organizations do not choose to do so. For the outcome analysis, we excluded blood NIMs that did not meet criteria for any NHSN-defined infections and postdischarge NIMs in which the positive blood culture occurred after discharge from the index hospitalization because hospital mortality, LOS, and cost would not be applicable for postdischarge NIMs.

We developed a blood NIM propensity model to predict the probability of blood NIMs during the index hospital stay. Candidate variables were demographics (age and sex), principal diagnosis-based disease groups (Clinical Classification Software; AHRQ, Rockville, MD), intensive care unit admission within 24 hours of inpatient admission, previous same-hospital admission within 30 days, admission from a skilled nursing facility, other acute care hospital, or long-term care facility, acute laboratory risk for mortality score,[10] and type of central line on admission.

We matched BSI cases with up to 5 noncases by propensity of blood NIM and exposure time (time from admission to onset of BSI), using a greedy-matching algorithm up to 3 decimals precision.[11] For patients without BSI, inpatient exposure time (LOS) was at least as long as the LOS before the onset of BSI in the matching BSI case.[12] The matching pool for the CLABSI cases consisted of patients hospitalized in our health care system during the study period with a

Table 1
NHSN definitions in place at the time of the study (2010-2011)[3,9]

Term	NHSN definition
LCBI	Patient meets at least 1 of the following criteria: 1. Patient has a recognized pathogen cultured from ≥1 blood cultures and organism cultured from blood is not related to an infection at another site; 2. Patient has at least 1 of the following signs or symptoms: fever (>38°C), chills, or hypotension and signs and symptoms and positive laboratory results are not related to an infection at another site and common skin commensal is cultured from ≥2 or more blood cultures drawn on separate occasions.
Qualified central line	An intravascular catheter that terminates at or close to the heart or in one of the great vessels which is used for infusion, withdrawal of blood, or hemodynamic monitoring.
Central line–associated bloodstream infection	LCBI in which a central line was in place at the time of, or within 48 h before, the event.

LCBI, laboratory-confirmed bloodstream infection; *NHSN*, National Health Safety Network.