ORIGINAL ARTICLE

Comparison of Hospitalwide Surveillance and Targeted Intensive Care Unit Surveillance of Healthcare-Associated Infections

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OBJECTIVES. To assess the surveillance coverage obtained with Centers for Disease Control and Prevention (CDC)–recommended surveillance of healthcare-associated infections (HAIs), which is focused on intensive care units (ICUs) and emphasizes device-related infections (ie, those associated with central venous catheters, ventilators, and/or urinary catheters), compared with the surveillance coverage achieved by comprehensive hospitalwide surveillance. In addition, we assessed whether the infection rates in step-down units more resemble those in wards or ICUs.

METHODS. Review of prospectively obtained, comprehensive hospitalwide surveillance data from 2004 through 2005 for an acute care tertiary care hospital with approximately 700 beds. Surveillance data was obtained by trained infection control professionals using standard CDC criteria for HAIs.

RESULTS. CDC-recommended ICU surveillance for catheter-related bloodstream infection (BSI) and ventilator-associated pneumonia would have detected only 87 (21.4%) of 407 catheter-related BSIs and only 66 (37.9%) of 174 respiratory tract infections that occurred in the medical and surgical services. Only 31 (34.8%) of 89 infections caused by methicillin-resistant *Staphylococcus aureus* and 7 (31.8%) of 22 infections caused by vancomycin-resistant *Enterococcus* occurred in our adult ICUs.

CONCLUSIONS. Rates of HAIs were highest in the ICUs, intermediate in step-down units, and lowest in the wards. The rates of infections in the step-down units were more similar to those in the wards than to those in the ICUs. To prevent HAIs, more comprehensive surveillance may be indicated.

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Healthcare-associated infections (HAIs) account for an estimated 1.7 million infections, 99,000 deaths, and $4.5 billion in excess healthcare costs annually.[1] Hospital-acquired bloodstream infection (BSI) alone has been estimated to be responsible for 26,250 deaths per year and ranks as the eighth leading cause of death in the United States.[2] Key interventions to control HAIs include surveillance,[3] hand hygiene,[4] and isolation of patients who have communicable diseases or who are infected and/or colonized with multidrug-resistant pathogens.[5] Surveillance provides data that allow the determination of endemic infection rates, early detection of epidemics, and assessment of the efficacy of interventions.

Since its inception, the National Nosocomial Infection Surveillance (NNIS) system, managed by the Centers for Disease Control and Prevention (CDC), has been the premier surveillance system for HAIs.[3,6,7] Initially, surveillance was conducted throughout the hospital, and infection rates were reported as infections per 100 admissions. In 1999, the NNIS system moved to targeted surveillance by focusing on device-related infections (ie, those associated with central venous catheters, ventilators, and/or urinary catheters) in intensive care units (ICUs).[8] These changes provided several advantages: (1) the focus was on the areas of the hospital with the highest rates of HAIs (ie, ICUs); (2) the focus was on the most common infections with the highest mortality rates (ie, ventilator-associated pneumonia and catheter-associated bloodstream infection); (3) infection rates were reported as true rates (ie, infections per 1,000 device-days), and rates were risk adjusted by type of device; and (4) efficiency was increased (ie, cost per infection identified was reduced) by focusing on device-related infections in ICUs.

In recent years, US hospitals have undergone many changes; patients have a higher acuity of illness and a shorter length of stay.[8-10] In addition, hospitals have increased the size and number of their ICUs.[10] More recently, hospitals have added step-down units (SDUs) to provide appropriate care for patients whose acuity of illness falls between that of ICU patients and that of ward patients. In general, SDUs manage patients who require central venous catheters and/or ventilators. Because of the changing hospital environment, we undertook an analysis of our prospectively collected surveillance data on HAIs in patients in the medical and surgical services

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at a university medical center to answer the following questions. First, if surveillance focuses on device-related infections in the ICU, what percentage of all nosocomial infections are detected? Second, is the infection rate in SDUs more similar to that in ICUs or that in wards? Third, does the nosocomial infection ratio (ie, the number of infections per 100 admissions) or the nosocomial infection rate (ie, the number of infections per 1,000 patient-days) provide a better delineation of the infections occurring among patients in the ICUs, SDUs, and wards? Fourth, how has the size of ICUs and SDUs and the number of admissions to these units changed over the past decade? Finally, what percentage of infections due to methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Enterococcus* (VRE) occur in the ICU?

METHODS

This study was conducted at the University of North Carolina Hospitals, at an acute care tertiary hospital with approximately 700 beds. During the period analyzed, 2004 through 2005, infection control surveillance was conducted by 5 infection control professionals (one of which was V.B.) supervised by 2 full-time faculty (D.J.W., W.A.R.). Comprehensive hospitalwide surveillance that included all CDC-defined sites was performed in accordance with CDC criteria.[11-13] Bloodstream infection (BSI) included both primary infections (ie, those not related to a secondary site) and secondary infections (ie, bacteremia associated with infection at another site). In accordance with CDC criteria, primary bloodstream infections were considered central catheter–associated if a catheter had been in place for more than 48 hours and a secondary site of infection was not present. Respiratory infections included pneumonia, tracheobronchitis, empyema, and other infections of the respiratory tract. Pneumonia was categorized as ventilator associated if the patient had been intubated and received ventilation for more than 48 hours prior to the development of pneumonia; otherwise, it was considered hospital-acquired pneumonia.

Sources for identification of nosocomial infections included laboratory reports of positive culture results, results of serological testing or polymerase chain reaction, morbidity and mortality conferences, autopsies, and reports of infections from clinics and physicians (eg, surgical site infections [SSIs]). Infections with onset 48 or more hours after admission were considered to be nosocomial. For patients who moved from one hospital location to another, infections that developed within 48 hours after admission to a new unit were categorized as occurring in the previous unit. Cases were entered into a computerized database after having been reviewed by a nurse supervisor and a physician who specialized in infectious diseases and critical care medicine. Although all cases of central line–associated BSI were identified, rates of central line-associated BSI were not calculated for ward patients, because denominator data (ie, the number of central line–days) were not collected until 2006. Patients receiving mechanical ventilation were cared for only in the ICUs or SDUs. Only adult patients in the medical or surgical services were included in this analysis, because only these 2 services had both ICUs and SDUs.

TABLE 1. Healthcare-Associated Infections (HAIs) in the Medical Service of the Study Hospitals, by Location, 2004-2005

Variable	Medical ICU	Medical SDU	Medical ward	*P*, ICU vs SDU	*P*, SDU vs ward	*P*, ICU vs ward
No. of admissions	2,196	2,505	16,656	…	…	…
No. of patient-days	10,643	7,750	72,781	…	…	…
BSI						
No. of cases	78	30	150	…	…	…
Cases per 100 admissions	3.55	1.20	0.90	<.001	NS	<.001
Cases per 1,000 device-days	7.33	3.87	2.06	<.01	<.01	<.001
Respiratory infections						
No. of cases	48	10	22	…	…	…
Cases per 100 admissions	2.19	0.40	0.13	<.001	<.01	<.001
Cases per 1,000 device-days	4.51	1.29	0.30	<.001	<.001	<.001
UTI						
No. of cases	65	27	116	…	…	…
Cases per 100 admissions	2.96	1.08	0.70	<.001	<.05	<.001
Cases per 1,000 device-days	6.11	3.48	1.59	<.05	<.001	<.001
All HAIs						
No. of cases	205	72	341	…	…	…
Cases per 100 admissions	9.34	2.87	2.05	<.001	<.01	<.001
Cases per 1,000 patient-days	19.26	9.29	4.69	<.001	<.001	<.001

NOTE. BSI, bloodstream infection; ICU, intensive care unit; NS, nonsignificant ($P > .05$); SDU, step-down unit; UTI, urinary tract infection.

TABLE 2. Healthcare-Associated Infections (HAIs) in the Surgical Service of the Study Hospital, by Location, 2004-2005

Variable	Surgical ICU	Surgical SDU	Surgical ward	*P*, ICU vs SDU	*P*, SDU vs ward	*P*, ICU vs ward
No. of admissions	1,063	3,117	14,829	…	…	…
No. of patient-days	5,531	6,587	73,999	…	…	…
BSI						
No. of cases	52	12	85	…	…	…
Cases per 100 admissions	4.89	0.38	0.57	<.001	NS	<.001
Cases per 1,000 device-days	9.40	1.82	1.15	<.001	NS	<.001
Respiratory infection						
No. of cases	49	12	33	…	…	…
Cases per 100 admissions	4.61	0.38	0.22	<.001	NS	<.001
Cases per 1,000 device-days	8.86	1.82	0.45	<.001	<.001	<.001
UTI						
No. of cases	45	19	200	…	…	…
Cases per 100 admissions	4.23	0.61	1.35	<.001	<.001	<.001
Cases per 1,000 device-days	8.14	2.88	2.70	<.001	NS	<.001
SSI						
No. of cases	15	7	74	…	…	…
Cases per 100 admissions	1.41	0.22	0.50	<.001	<.05	<.001
Cases per 1,000 patient-days	2.71	1.06	1.00	<.05	NS	<.001
All HAIs						
No. of cases	171	91	411	…	…	…
Cases per 100 admissions	16.09	2.92	2.77	<.001	NS	<.001
Cases per 1,000 patient-days	30.92	13.82	5.55	<.001	<.001	<.001

NOTE. BSI, bloodstream infection; ICU, intensive care unit; NS, nonsignificant ($P > .05$); SDU, step-down unit; SSI, surgical site infection; UTI, urinary tract infection.

Data available from this prospectively maintained database include the patient's name, age, sex, admission date, date of infection onset, hospital location, site of infection, presence of indwelling device(s), and infecting pathogen(s). The antimicrobial susceptibilities of the infecting pathogens were recorded on patient case forms but were not entered into the computerized database, with the exception of methicillin-resistance in *S. aureus* and vancomycin-resistance in *Enterococcus* species. Only pathogens associated with nosocomial infections that met CDC criteria were included in our database (ie, patients who were colonized were not included in this study).

The infection ratio was defined as the number of nosocomial infections per 100 admissions for the selected unit.[14] This definition was widely used to report HAIs prior to 1999.[15] The infection rate was defined as the number of nosocomial infections per 1,000 patient-days. Device-associated infection rates were calculated as the number of device-associated infections for a specified body site per 1,000 device days.[16] The device utilization ratio was calculated as the number of device-days per number of patient-days. Statistical significance was determined by 2-tailed χ^2 tests, with a Yates correction, if necessary.

RESULTS

In the period studied, 2004 through 2005, a total of 21,357 patients were admitted to the medical service, and 19,009 were admitted to the surgical service. Overall, 618 nosocomial infections occurred in medical service patients, and 673 nosocomial infections occurred in surgical service patients.

Changes in the Medical and Surgical Services, 1995 vs 2005

From 1995 through 2005, the number of beds in the medical service increased by 17.0%, and the number of admissions increased by 18.7%. Although admissions to the surgical service also increased substantially (by 19.5%), the total number of beds in this service only increased slightly (2.7%). From 1995 through 2005, the number of medical ICU beds ($N = 16$) and the number of surgical ICU beds ($N = 8$) remained stable, while admissions decreased (medicine, −8.9%; surgery, −23.3%). In 1995, our hospitals had a combined medical and surgical SDU. By 2005, each department had its own SDU; the total number of SDU beds had increased from 5 to 24, and admissions had increased from 677 to 2,849, an increase of over 300%. Admissions to the medical and surgical wards increased modestly from 1995 through 2005 (medical wards, 11.4%; surgical wards, 6.4%).

HAIs by Site of Care

In the medical service, the ICU accounted for 10.3% of admissions and 11.7% of patient-days. Overall, 30.2% of the BSIs, 60.0% of the respiratory infections, and 31.3% of the

TABLE 3. Device-Related Infection Rates in the Study Hospital, by Service and Unit, 2004-2005

Device, variable	Medical ICU	Medical SDU	Surgical ICU	Surgical SDU
Catheter				
No. of cases of CA-BSI	58	22	29	11
No. of central line–days	9,784	3,255	4,779	4,084
Cases of CA-BSI per 1,000 central line–days	5.93	6.76	6.07[a]	2.69[a]
Central line utilization rate	0.92	0.42	0.86	0.62
Ventilator				
No. of cases of VAP	36	0	30	0
No. of ventilator-days	6,062	310	4,021	36
Cases of VAP per 1,000 ventilator-days	5.94	0.00	7.46	0.00
Ventilator utilization rate	0.57	0.04	0.73	0.01

NOTE. Utilization rate was calculated as total device-days divided by total patient-days. CA-BSI, catheter-associated bloodstream infection; ICU, intensive care unit; SDU, step-down unit; VAP, ventilator-associated pneumonia.

[a] $P < .05$ comparing ICU and SDU by service (medicine and surgery).

urinary tract infections (UTIs) that occurred in the hospital occurred in the medical ICU (Table 1). The infection ratio was highest in the ICU, followed by the SDU, and lowest in the wards. Similarly, the infection rate was highest on the ICU, followed by the SDU, and lowest in the wards. This trend was similar for each type of infection analyzed (ie, BSI, respiratory tract infection, and UTI). All differences were statistically significant, with a single exception. The difference between the SDU and the ward was more apparent when they were compared in terms of the infection rate, rather than the infection ratio.

In the surgical service, the ICU accounted for 5.6% of admissions and 6.4% of patient-days. Overall, 34.9% of the BSIs, 52.1% of the respiratory infections, 17.0% of the UTIs, and 15.6% of the SSIs that occurred in the hospital occurred in the surgical ICU (Table 2). For each type of infection, the infection ratio was highest in the ICU, followed by the wards, and lowest in the SDU, with the exception of respiratory infections. However, the infection rate was highest on the ICU, followed by the SDU, and lowest in the wards. The differences between the ICU, SDU, and ward were more apparent if they were compared in terms of the infection rate, rather than the infection ratio, because the infection rate accounted for patients' shorter stay in the SDU, compared with patients' stay in the ward.

Overall, the nosocomial infection rate in the SDU was more similar to the infection rate in the ward, rather than the rate in the ICU.

Device-Related Infections

Most device-related infections occurred in the ICU, rather than the SDU. The rate of ventilator-associated pneumonia was higher in the ICU, compared with the SDU, but this difference was not significant (Table 3). The rate of catheter-associated BSI was statistically significantly higher in the sur-

TABLE 4. Healthcare-Associated Infections Due To Antibiotic-Resistant Pathogens in the Study Hospital, by Service and Location, 2004-2005

Infection, rate	Medical ICU	Medical SDU	Medical wards	Surgical ICU	Surgical SDU	Surgical wards
MRSA						
No. of cases	19	2	19	12	7	30
Cases per 100 admissions	0.87[a]	0.08[a]	0.11	1.13[a]	0.22[a]	0.20
Cases per 1,000 patient-days	1.79[a]	0.26[a]	0.26	2.17	1.06[b]	0.41[b]
VRE						
No. of cases	2	0	6	5	2	7
Cases per 100 admissions	0.09	0.00	0.04	0.47[a]	0.06[a]	0.05
Cases per 1,000 patient-days	0.19	0.00	0.08	0.90	0.30	0.09

NOTE. ICU, intensive care unit; MRSA, methicillin-resistant *Staphylococcus aureus*;SDU, step-down unit; VRE, vancomycin-resistant enterococci.

[a] $P < .05$ for comparison of ICU and SDU by service (medicine and surgery).

[b] $P < .05$ for comparison of SDU and specialty ward(s) by service (medicine and surgery).

gical ICU, compared with the surgical SDU, but this was not the case when the medical ICU was compared with the medical SDU (Table 3). In the medical ICU and SDU, 74.1% of BSIs and 62.1% of respiratory infections were device related. In the surgical ICU and SDU, 62.5% of BSIs and 49.2% of respiratory infections were device related.

Overall, only 37% of healthcare-associated BSIs were device related. Of the 63% of BSIs that were not device related, 18% occurred in the ICU, 13% in the SDU, and 32% in a medical or surgical ward. Overall, only 21% of healthcare-associated respiratory tract infections were device related. Of the 79% of respiratory tract infections that were not device related, 11% occurred in the ICU, 10% in the SDU, and 58% in a medical or surgical ward.

HAIs Due to MRSA or VRE

The rates of infections due to MRSA or VRE were highest in the ICUs (Table 4). In the medical service, 47.5% of MRSA infections and 25% of VRE infections occurred in the ICU. In the surgical service, 24.5% of MRSA infections and 35.7% of VRE infections occurred in the ICU.

DISCUSSION

The Study on the Efficacy of Nosocomial Infection Control project demonstrated more than 20 years ago that "essential components of effective [infection control] programs included conducting organized surveillance and control activities."[17(p182)] Surveillance is especially critical for assessing the effectiveness of interventions designed to reduce the prevalence of HAIs, and precise, risk-adjusted measurements of infection rates are essential for comparing HAI rates among different healthcare facilities. In the 1970s and 1980s, HAI rates were described with the nosocomial infection ratio (ie, number of infections per 100 admissions). This definition ignored the length of stay and was not risk adjusted. However, since the late 1980s, HAI rates have been described with the nosocomial infection rate (ie, the number of infections per 1,000 patient-days). This allows risk adjustment for length of stay. Our data demonstrated that the infection rate provides a better delineation of the impact of nosocomial infections across different types of adult units (ie, ICU, SDU, or ward), and that the infection rate in the SDU was more similar to the infection rate in the wards.

Recently, the Institute for Medicine publications *To Err is Human*[18] and *Microbial Threats to Health*[19] called attention to the dramatic impact of nosocomial infections on patient morbidity and mortality. The CDC estimates that HAIs account for 2 million infections and 90,000 deaths annually.[1] The high number of deaths due to HAIs has sparked great concern among the public and led to the movement to make nosocomial infections rates publicly reported. The medical profession has responded with measures aimed at reducing nosocomial infections by such means as instituting recommendations of the Institute for Healthcare Improvement (IHI) in its 100,000 Lives campaign, which include "bundles" of interventions designed to reduce rates of ventilator-associated pneumonia, central catheter–associated BSI, and SSI throughout the hospital.[20,21] However, the IHI campaign suggested initial implementation in the ICU.

Over the past decade, hospital care and the distribution of hospital beds have shifted to ICUs and SDUs. Our data demonstrate that from 1995 through 2005, the number of adult medical and surgical beds in our facility only increased 13% (from 256 to 290), and the number of ICU beds remained stable. During the same time, the number of SDU beds increased 380%, from 5 to 24. Our data demonstrate that ICU-focused surveillance that emphasizes device-related infections is indeed highly efficient, because ICU patients have the highest rate of infections; however, surveillance limited to device-related infections in ICUs detected only 21% of BSIs and 37% of respiratory infections. This is not surprising, because although the proportion of patients with a central venous catheter may be lower outside the ICU, the number of patients with a central venous catheter in non-ICU wards is much larger. For example, Climo and colleagues,[22] in a cross-section study of 6 medical centers, reported that ward patients used more than twice as many central venous catheters as did ICU patients. The rates of catheter-associated BSI were lower in both the medical and surgical SDUs, but catheter-associated BSI occurring in the SDU constituted 27.5% of all catheter-associated BSI. This highlights the importance of hospitals implementing the IHI "bundle" of interventions to reduce catheter-associated BSI in areas other than adult ICUs.

Similarly, surveillance that focuses on adult ICUs detects fewer than 50% of infections due to MRSA or VRE. Further efforts to control MRSA and VRE in hospitals must also focus on identifying and preventing person-to-person transmission outside the ICU, especially because there is a continuous flow of patients to and from the ICU. Although efforts to reduce the impact of HAIs should focus on the infections with the highest mortality (ie, catheter-associated BSI and ventilator-associated pneumonia), infection control professionals should reassess the value of comprehensive hospitalwide surveillance when designing and assessing the validity of interventions to reduce all HAIs.

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