



Online article and related content
current as of February 17, 2009.

Methicillin-Resistant *Staphylococcus aureus* Central Line Associated Bloodstream Infections in US Intensive Care Units, 1997-2007

Deron C. Burton; Jonathan R. Edwards; Teresa C. Horan; et al.

JAMA. 2009;301(7):727-736 (doi:10.1001/jama.2009.153)

<http://jama.ama-assn.org/cgi/content/full/301/7/727>

Supplementary material

JAMA Report Video

<http://jama.ama-assn.org/cgi/content/full/301/7/727/DC1>

Correction

[Contact me if this article is corrected.](#)

Citations

[This article has been cited 1 time.](#)

[Contact me when this article is cited.](#)

Topic collections

Bacterial Infections; Infectious Diseases, Other; Critical Care/ Intensive Care Medicine; Adult Critical Care; Public Health; Public Health, Other; Hematology/ Hematologic Malignancies; Hematology, Other; Infectious Diseases
[Contact me when new articles are published in these topic areas.](#)

Related Articles published in the same issue

Decreasing MRSA Infections: An End Met by Unclear Means
[Michael William Climo. JAMA. 2009;301\(7\):772.](#)

Subscribe

<http://jama.com/subscribe>

Permissions

permissions@ama-assn.org

<http://pubs.ama-assn.org/misc/permissions.dtl>

Email Alerts

<http://jamaarchives.com/alerts>

Reprints/E-prints

reprints@ama-assn.org

Methicillin-Resistant *Staphylococcus aureus* Central Line–Associated Bloodstream Infections in US Intensive Care Units, 1997-2007

Deron C. Burton, MD, JD, MPH

Jonathan R. Edwards, MStat

Teresa C. Horan, MPH

John A. Jernigan, MD

Scott K. Fridkin, MD

STAPHYLOCOCCUS AUREUS IS A common cause of potentially serious and costly health care–associated infections presenting frequently in hospitals as central line–associated bloodstream infections (BSIs).¹ The emergence of methicillin-resistant *S aureus* (MRSA) as a prominent pathogen in health care settings has drawn the attention of clinicians, public health agencies, policy makers, and the public.²⁻⁷ Spurred in part by the perception that the prevention practices currently in use in US hospitals are not effectively controlling health care–associated MRSA infections, several state legislatures recently have considered or passed laws to mandate MRSA prevention activities in health care settings, particularly in intensive care units (ICUs).^{8,9}

Despite these events, a critical assessment of recent temporal trends in the incidence of health care–associated MRSA disease in the United States is lacking. This is crucial to inform public health policy decisions and formulate strategies for preventing MRSA health care–associated infections. During the past decade, efforts to prevent central line–associated BSIs in ICU patients, who often are at increased risk

Context Concerns about rates of methicillin-resistant *Staphylococcus aureus* (MRSA) health care–associated infections have prompted calls for mandatory screening or reporting in efforts to reduce MRSA infections.

Objective To examine trends in the incidence of MRSA central line–associated bloodstream infections (BSIs) in US intensive care units (ICUs).

Design, Setting, and Participants Data reported by hospitals to the Centers for Disease Control and Prevention (CDC) from 1997-2007 were used to calculate pooled mean annual central line–associated BSI incidence rates for 7 types of adult and non-neonatal pediatric ICUs. Percent MRSA was defined as the proportion of *S aureus* central line–associated BSIs that were MRSA. We used regression modeling to estimate percent changes in central line–associated BSI metrics over the analysis period.

Main Outcome Measures Incidence rate of central line–associated BSIs per 1000 central line days; percent MRSA among *S aureus* central line–associated BSIs.

Results Overall, 33 587 central line–associated BSIs were reported from 1684 ICUs representing 16 225 498 patient-days of surveillance; 2498 reported central line–associated BSIs (7.4%) were MRSA and 1590 (4.7%) were methicillin-susceptible *S aureus* (MSSA). Of evaluated ICU types, surgical, nonteaching-affiliated medical-surgical, cardiothoracic, and coronary units experienced increases in MRSA central line–associated BSI incidence in the 1997-2001 period; however, medical, teaching-affiliated medical-surgical, and pediatric units experienced no significant changes. From 2001 through 2007, MRSA central line–associated BSI incidence declined significantly in all ICU types except in pediatric units, for which incidence rates remained static. Declines in MRSA central line–associated BSI incidence ranged from –51.5% (95% CI, –33.7% to –64.6%; $P < .001$) in nonteaching-affiliated medical-surgical ICUs (0.31 vs 0.15 per 1000 central line days) to –69.2% (95% CI, –57.9% to –77.7%; $P < .001$) in surgical ICUs (0.58 vs 0.18 per 1000 central line days). In all ICU types, MSSA central line–associated BSI incidence declined from 1997 through 2007, with changes in incidence ranging from –60.1% (95% CI, –41.2% to –73.1%; $P < .001$) in surgical ICUs (0.24 vs 0.10 per 1000 central line days) to –77.7% (95% CI, –68.2% to –84.4%; $P < .001$) in medical ICUs (0.40 vs 0.09 per 1000 central line days). Although the overall proportion of *S aureus* central line–associated BSIs due to MRSA increased 25.8% ($P = .02$) in the 1997-2007 period, overall MRSA central line–associated BSI incidence decreased 49.6% ($P < .001$) over this period.

Conclusions The incidence of MRSA central line–associated BSI has been decreasing in recent years in most ICU types reporting to the CDC. These trends are not apparent when only percent MRSA is monitored.

JAMA. 2009;301(7):727-736

www.jama.com

for developing health care–associated infections, have intensified.^{10,11} More recently, technological and system-based approaches to improve the safety of central line insertion and han-

Author Affiliations are listed at the end of this article.
Corresponding Author: Deron C. Burton, MD, JD, MPH, Surveillance Branch, Division of Healthcare Quality Promotion, National Center for Preparedness, Detection, and Control of Infectious Diseases, Centers for Disease Control and Prevention, Mailstop A-24, 1600 Clifton Rd NE, Atlanta, GA 30333 (dburton@cdc.gov).

For editorial comment see p 772.

dling¹²⁻¹⁷ have been complemented by prevention measures focused on interrupting MRSA transmission between hospitalized patients.^{18,19}

To provide information on recent changes in the burden of MRSA disease, we sought to characterize trends in the incidence of MRSA and methicillin-susceptible *S aureus* (MSSA) central line–associated BSIs among adult and non-neonatal pediatric patients in ICUs, using national health care–associated infection surveillance data reported to the Centers for Disease Control and Prevention (CDC) from 1997 through 2007.

METHODS

Surveillance Processes and Definitions

The CDC's National Nosocomial Infections Surveillance (NNIS) system began in 1970 as a voluntary, hospital-based reporting system to monitor health care–associated infections and inform local and national prevention efforts. Participation in NNIS increased from 62 hospitals in 31 states in 1970 to almost 300 hospitals in 37 states in 2004, when NNIS data reporting concluded. The NNIS system was succeeded by the CDC's National Healthcare Safety Network (NHSN), a Web-based surveillance system that was phased in during 2005 and began providing data from former NNIS participants in 2006. A sharp increase in NHSN participation began in 2007 as a result of open enrollment and enactment of several state laws mandating health care–associated infection reporting to NHSN. For this analysis, data reported to NNIS from 1997 through 2004 and to NHSN from 2006 through 2007 were used. Surveillance data are not available from NHSN for 2005.

Both NHSN and NNIS surveillance processes are described in detail on the CDC Web site²⁰ and in previous publications.²¹ Briefly, in both systems, facilities choose the patient care areas under surveillance and perform surveillance for an entire calendar month for each area chosen. Facilities also choose the types of health care–associated infections to monitor. When

central line–associated BSI is chosen, local infection control professionals use standard methods and definitions to identify and report all central line–associated BSIs, patient-days, and patient central line days for selected ICUs during each month of surveillance activity.

Both NNIS and NHSN define *central line–associated BSI* as a primary bloodstream infection (ie, the bloodstream infection is not the result of a primary infection at another body site) in a patient who had a central line within the 48-hour period before the development of the BSI. There is no minimum period during which the central line must be in place for the BSI to be considered central line associated. Furthermore, a *central line* is defined as an intravascular catheter that terminates at or close to the heart or in 1 of the great vessels that is used for infusion, withdrawal of blood, or hemodynamic monitoring. The following are considered great vessels for the purpose of reporting central line–associated BSI infections and counting central line days: aorta, pulmonary artery, superior vena cava, inferior vena cava, brachiocephalic veins, internal jugular veins, subclavian veins, external iliac veins, and common femoral veins. Antibiotic susceptibility data as determined by the facility's laboratory are reported for up to 3 pathogens per central line–associated BSI.

Although the basic surveillance methodology was unchanged from NNIS to NHSN, there were minor revisions of the central line–associated BSI surveillance definition and the categories used for reporting data from pediatric ICUs.²⁰ To ensure uniform definitions and groupings across the entire analysis period, we limited the current trend analysis to central line–associated laboratory-confirmed (specifically, culture-positive) BSIs, as defined under NNIS and NHSN surveillance protocols (BOX),^{20,21} and aggregated all non-neonatal pediatric ICU data. A study of the accuracy of nosocomial bloodstream infection reporting under NNIS from 1991 through

1993 demonstrated a sensitivity, specificity, and positive predictive value of 85%, 98.3%, and 87%, respectively.²²

Selection of Patient Care Areas

We characterized trends separately for the following ICU types, for which at least 100 units of each type reported data during the analysis period: medical, surgical, combined medical-surgical units in facilities with a major affiliation with a medical school teaching program, combined medical-surgical units in facilities without such an affiliation, cardiothoracic, coronary, and pediatric units. Trends were analyzed separately for combined medical-surgical units with and without a major teaching affiliation because historical NNIS data show that central line–associated BSI incidence rates in combined medical-surgical units differ by teaching status.²³

Evaluation of Trends

Two MRSA metrics were evaluated. First, we calculated pooled mean central line–associated BSI incidence as the number of central line–associated BSIs per 1000 central line days per year for all central line–associated BSIs and separately for those associated with MRSA and MSSA. Second, we calculated pooled mean percent MRSA as the number of central line–associated BSIs associated with MRSA divided by the sum of MRSA and MSSA central line–associated BSIs by year (ie, proportion of all central line–associated BSIs due to *S aureus* that tested resistant to methicillin, oxacillin, or nafcillin [MRSA]). Pooled mean percent MRSA aggregated across ICU types traditionally has been the metric reported from NNIS,²⁴ so to compare percent MRSA and MRSA incidence as measures of the MRSA problem over time, we aggregated data across ICU types (FIGURE 1). Because aggregated MRSA central line–associated BSI incidence increased during the first half of the analysis period (through 2001) and thereafter declined during the latter half of the analysis period (Figure 1), we modeled the periods before and after 2001 separately to more accurately characterize

trends in MRSA central line–associated BSI incidence by ICU type.

Statistical Analysis

We used Poisson regression to model trends in central line–associated BSI incidence and weighted linear regression to model trends in percent MRSA. Model results were used to estimate percentage changes in each metric over the analysis period. All central line–associated BSI incidence values reported in the text are model-estimated; actual incidence data are shown in the figures.

Because of a significant interaction between ICU type and time in the aggregated model of MRSA central line–associated BSI incidence ($P = .001$ in Type III analysis with 6 degrees of freedom), separate models were evaluated for each ICU type. To explore whether variability in the reporting population due to movement of facilities in and out of either surveillance system had a substantial effect on our initial results, we confirmed trends observed in the aggregated data by performing subanalyses for each ICU type that were limited to units reporting at least 1 month of data and 50 central line days in each of the 10 surveillance years, rather than reporting data during any month of the analysis period. For display purposes, log-linear models of annual trends were used to estimate 2005 central line–associated BSI incidence rates in plotted graphs. For ICU types without significant annual trends, 2005 incidence estimates were derived from intercept-only models and represent mean annual central line–associated BSI incidence rates. Statistical analyses were performed using SAS version 9.1 software (SAS Institute Inc, Cary, North Carolina). All reported P values are 2-sided, and a P value of $\leq .05$ was considered statistically significant.

The institutional review board of the National Center for Preparedness, Detection, and Control of Infectious Diseases, CDC, conducted an ethical review and approved the routine reporting of health care–associated infection data to NNIS and NHSN, determining

Box. Definition of Laboratory-Confirmed Bloodstream Infections Under the National Nosocomial Infections Surveillance System and the National Healthcare Safety Network

Criterion 1

Patient has a recognized pathogen cultured from 1 or more blood cultures and

Organism cultured from blood is not related to an infection at another site

Criterion 2

Patient has at least 1 of the following signs or symptoms:

Fever, temperature higher than 38°C

Chills

Hypotension

Hypothermia, temperature lower than 37°C, if patient is less than or equal to 1 year old

Apnea, if patient less than or equal to 1 year old, or

Bradycardia, if patient less than or equal to 1 year old

and

Presence of at least 1 of the following^a:

Common skin contaminant (eg, diphtheroids, *Bacillus* species, *Propionibacterium* species, coagulase-negative staphylococci, or micrococci) is cultured from 2 or more blood cultures drawn on separate occasions

or

Common skin contaminant is cultured from at least 1 blood culture from a patient with an intravascular line, and the physician institutes appropriate antimicrobial therapy

and

Signs and symptoms and positive laboratory results are not related to an infection at another site

^aThe definition of laboratory-confirmed bloodstream infection used under the National Nosocomial Infections Surveillance (NNIS) system included a positive antigen test on blood as an additional option under this criterion, but the antigen test option was not present under the National Healthcare Safety Network definition. Laboratory-confirmed bloodstream infections that were reported under NNIS based on a positive antigen test on blood were excluded from analysis.

that such reporting constitutes surveillance and not research. Our examination of temporal trends in these surveillance data likewise is not human subjects research and not subject to further institutional review.

RESULTS

Facility Characteristics and Distribution of Reported Central Line–Associated BSIs

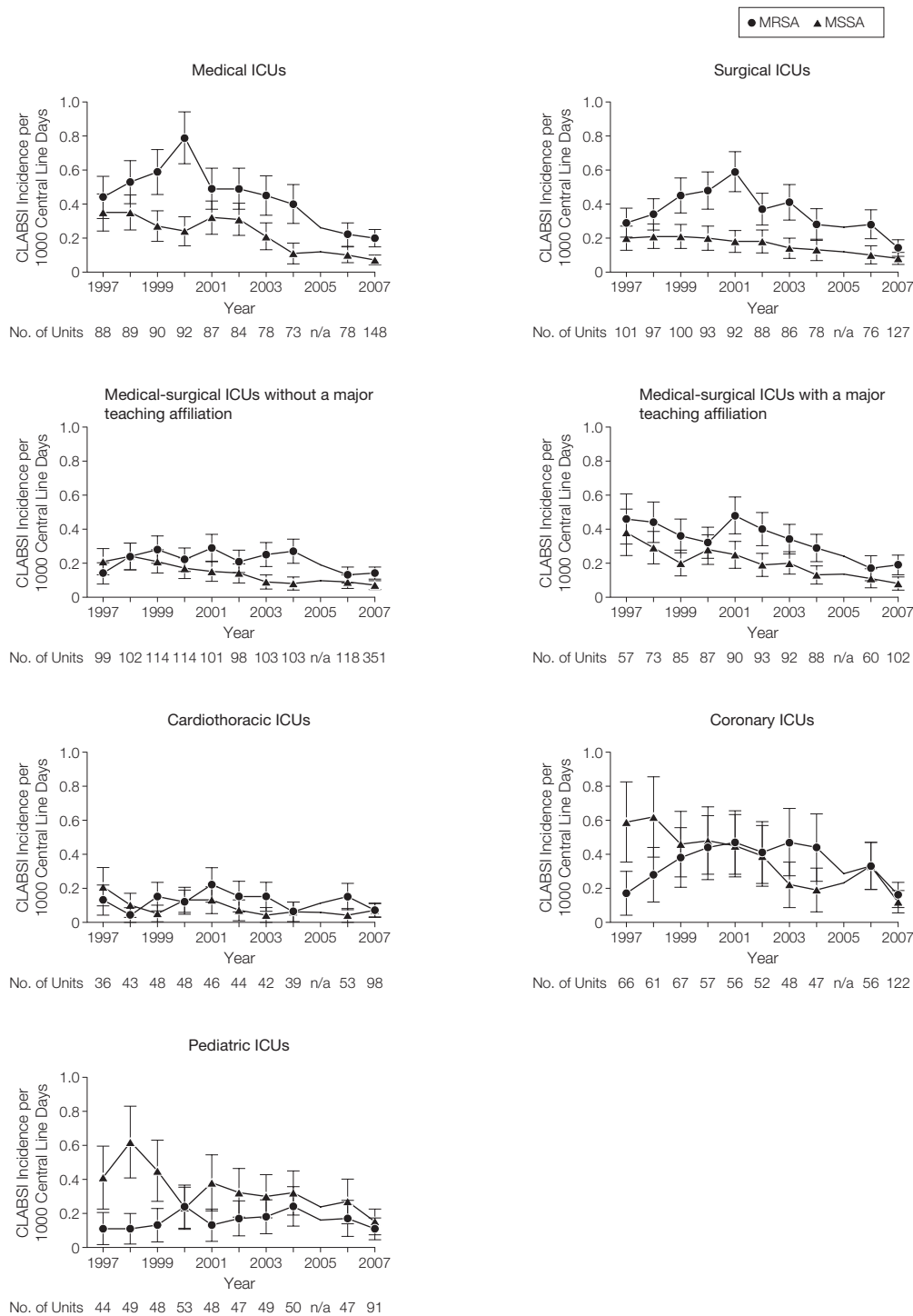
From 1997 through 2007, 1684 ICUs representing 16 225 498 patient-days reported central line–associated BSI data to the CDC. In total, 599 facilities, geo-

graphically dispersed among 43 states and the District of Columbia, reported central line–associated BSI data at some time during the analysis period, but not all facilities reported continuously throughout the analysis period. Before 2007, the median number of facilities participating in any given surveillance year was 244 (range, 219–263); in 2007, participation increased to 518 facilities, primarily due to influxes of participants from New York, South Carolina, and Colorado. Of the ICU types reporting, 491 were combined medical-surgical units without a

To more completely characterize annual trends in *S aureus* central line-associated BSI incidence, trend data also were stratified by ICU type (FIGURE 2 and TABLE 2). For 4 ICU types (surgical, medical-surgical without a major teaching affiliation, cardiothoracic, and coronary units), MRSA central line-associated BSI incidence rates significantly increased from 1997 through 2001, whereas in the remaining 3 ICU types (medical, medical-surgical with

Downloaded from www.jama.com at CDC-Information Center on February 17, 2009

Figure 2. Trends in Incidence of *Staphylococcus aureus* Central Line–Associated Bloodstream Infections by Intensive Care Unit Type—National Nosocomial Infections Surveillance System, 1997-2004; National Healthcare Safety Network, 2006-2007



Magnitudes of changes in incidence rates during the analysis period are reported in Table 2. Central line–associated bloodstream infection (CLABSI) incidence for 2005 is estimated from log-linear models of the annual CLABSI trend or, where no trend was present, from intercept-only models. (No 2005 data are available from either surveillance system.) ICU indicates intensive care unit; error bars, 95% confidence intervals; MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-susceptible *S aureus*.

a major teaching affiliation, and pediatric units) there were no significant changes in MRSA central line–associated BSI incidence during this period.

From 2001 through 2007, MRSA central line–associated BSI incidence declined significantly in all 6 adult ICU types and was stable in pediatric ICUs. Changes in MRSA central line–associated BSI incidence ranged from –51.5% (95% CI, –33.7% to –64.6%; $P < .001$) in medical-surgical ICUs without a major teaching affiliation to –2.4% (95% CI, –31.8% to 40.2%; $P = .90$) in medical-surgical ICUs with a major teaching affiliation.

(0.31 vs 0.15 central line–associated BSIs per 1000 central line days) to –69.2% (95% CI, –57.9% to –77.7%; $P < .001$) in surgical ICUs (0.58 vs 0.18 central line–associated BSIs per 1000 central line days).

In every ICU type, MSSA central line–associated BSI incidence declined continuously and significantly from 1997 through 2007, with estimated incidence changes ranging from –60.1% (95% CI, –41.2% to –73.1%; $P < .001$) in surgical ICUs (0.24 vs 0.10 central line–associated BSIs per 1000 central

line days) to –77.7% (95% CI, –68.2% to –84.4%; $P < .001$) in medical ICUs (0.40 vs 0.09 central line–associated BSIs per 1000 central line days; Figure 2 and Table 2).

Total Central Line–Associated BSI Trends by ICU Type

Because *S aureus* is one of the most common pathogens associated with central line–associated BSIs in ICUs reporting to the CDC, we evaluated whether observed decreases in MRSA and MSSA central line–associated BSI incidence

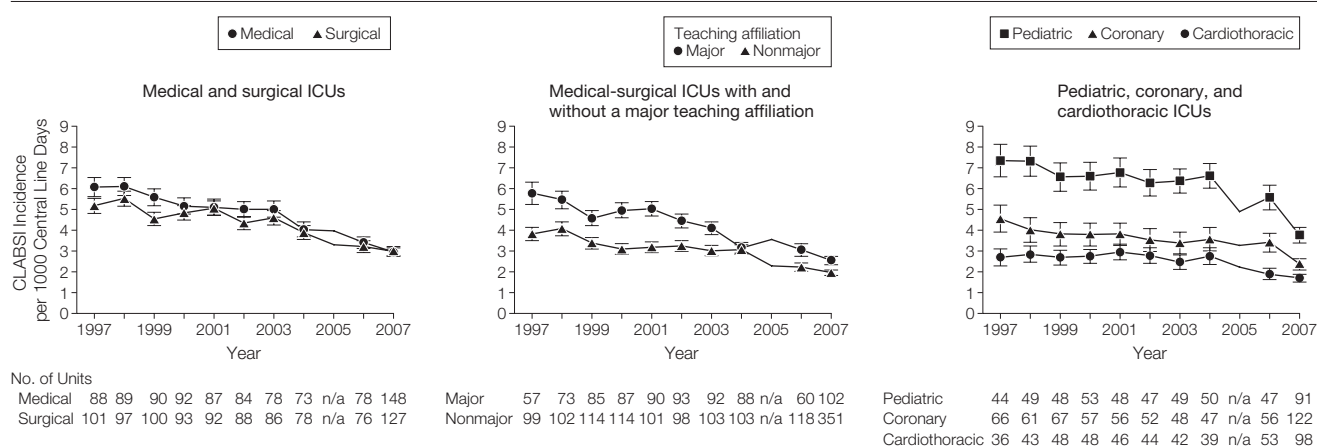
Table 2. Characterization of Trends in Incidence Rates of MRSA and MSSA Central Line–Associated Bloodstream Infections by Intensive Care Unit Type—National Nosocomial Infections Surveillance System, 1997–2004; National Healthcare Safety Network, 2006–2007

Intensive Care Unit Type	Change in Incidence of Central Line–Associated Bloodstream Infection ^a					
	MRSA				MSSA	
	1997–2001		2001–2007		1997–2007	
	Relative % Change (95% CI)	P Value	Relative % Change (95% CI)	P Value	Relative % Change (95% CI)	P Value
Medical	28.0 (–5.0 to 72.8)	.10	–63.8 (–51.3 to –73.1)	<.001	–77.7 (–68.2 to –84.4)	<.001
Surgical	101.9 (48.9 to 174.7)	<.001	–69.2 (–57.9 to –77.7)	<.001	–60.1 (–41.2 to –73.1)	<.001
Medical-surgical						
Without major teaching affiliation	54.4 (2.5 to 134.2)	.04	–51.5 (–33.7 to –64.6)	<.001	–70.6 (–57.5 to –79.8)	<.001
With major teaching affiliation	–2.4 (–31.8 to 40.2)	.90	–63.2 (–48.8 to –73.8)	<.001	–72.9 (–59.8 to –81.8)	<.001
Cardiothoracic	136.7 (4.7 to 456.4)	.04	–55.1 (–17.6 to –75.9)	.01	–63.4 (–27.3 to –82.0)	.005
Coronary	135.0 (24.8 to 352.7)	.009	–58.4 (–33.8 to –74.1)	<.001	–73.2 (–58.6 to –82.8)	<.001
Pediatric	61.5 (–34.8 to 311.1)	.31	–20.6 (–59.4 to 53.8)	.50	–61.7 (–40.8 to –75.4)	<.001

Abbreviations: CI, confidence interval; MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-susceptible *S aureus*.

^aChange in incidence is calculated as the relative change between the model-estimated annual incidence at the end compared with the beginning of the specified time period.

Figure 3. Trends in Incidence of Central Line–Associated Bloodstream Infections by Intensive Care Unit Type—National Nosocomial Infections Surveillance System, 1997–2004; National Healthcare Safety Network, 2006–2007



The 2005 central line–associated bloodstream infection (CLABSI) rate is estimated from a log-linear model of the annual CLABSI trend for each intensive care unit (ICU) type. (No 2005 data are available from either surveillance system.) Error bars indicate 95% confidence intervals. Magnitudes of changes in incidence rates during the analysis period are reported in Table 3.

rates were reflective of overall decreases in central line–associated BSI rates. Like MSSA central line–associated BSI incidence, the incidence of central line–associated BSI associated with any pathogen decreased continuously and significantly ($P < .001$) from 1997 through 2007 in all ICU types studied (FIGURE 3 and TABLE 3). Declines in central line–associated BSI incidence ranged from –38.2% (95% CI, –29.4% to –45.9%) in coronary ICUs (4.81 vs 2.97 central line–associated BSIs per 1000 central line days) to –54.2% (95% CI, –50.2% to –57.9%) in medical-surgical ICUs with a major teaching affiliation (6.65 vs 3.04 central line–associated BSIs per 1000 central line days).

Sensitivity Analyses of Central Line–Associated BSI Trends

Analyses of the subset of ICUs reporting at least 1 month of data in each of the 10 surveillance years of the analysis period showed results similar to those of the entire study data set, which used data from all ICUs (Table 3). The subset analyses were intended to test whether trends observed using data from all ICUs could be explained by variations in the facilities reporting central line–associated BSI data during the analysis period. We also examined the

effect of the influx of new NHSN participants in 2007 by excluding 2007 data from ICUs that had not reported in at least 1 prior surveillance year; this exclusion did not significantly alter 2007 pooled mean central line–associated BSI incidence rates or modeled incidence trends for any ICU type.

To examine whether declines in MRSA central line–associated BSI incidence preceded the transition from NNIS to NHSN, we analyzed the trend in aggregated MRSA central line–associated BSI incidence from 2001 through 2004 using NNIS data alone and found a significant decline (relative change, –28.9%, 95% CI –16.6% to –39.4%; $P < .001$; 0.38 vs 0.27 central line–associated BSIs per 1000 central line days) consistent with the overall decline observed from 2001 through 2007 (relative change, –61.5%, 95% CI –55.7% to –66.5%; $P < .001$; 0.43 vs 0.17 central line–associated BSIs per 1000 central line days).

COMMENT

Our results show that the 6 most common adult ICU types reporting central line–associated BSIs to the CDC, which together account for 96% of all reported MRSA central line–associated BSIs among studied ICU types, have ex-

perienced declines of 50% or more in the incidence of MRSA central line–associated BSI since 2001. This means that the risk of primary MRSA bloodstream infections among patients with central lines in these ICUs has substantially decreased in recent years. In pediatric ICUs, this risk has not significantly increased but, rather, has been stable over the past decade. Data aggregated across ICU types showed trends of increasing MRSA central line–associated BSI incidence and decreasing MSSA central line–associated BSI incidence through 2001, after which MRSA central line–associated BSI incidence also decreased (Figure 1).

These observations suggest that different factors may have contributed to trends in the risk of MRSA vs MSSA central line–associated BSI. *S aureus* is a common cause of central line–associated BSI; therefore, the observed MRSA trends may have been influenced in part by the same factors responsible for the observed declines of roughly 40% to 50% in total (ie, non-pathogen specific) central line–associated BSI incidence rates in the ICU types evaluated (Table 3).

These trends in total central line–associated BSI incidence continue the declines reported in NNIS ICUs from

Table 3. Trends in Incidence of Central Line–Associated Bloodstream Infection by Intensive Care Unit Type and Duration of Participation in Centers for Disease Control and Prevention Surveillance From 1997–2007^a

Intensive Care Unit Type	Change in Incidence of Central Line–Associated Bloodstream Infection ^b					
	All ICUs Reporting Data During Any Month of Surveillance Years 1997–2007			ICUs Reporting Data for at Least 1 Month of Each Surveillance Year, 1997–2007 ^c		
	No. of ICUs	Relative % Change (95% CI)	P Value	No. of ICUs ^d	Relative % Change (95% CI)	P Value
Medical	247	–50.8 (–47.2 to –54.3)	<.001	18	–54.8 (–47.4 to –61.2)	<.001
Surgical	245	–42.2 (–37.8 to –46.3)	<.001	15	–33.3 (–19.6 to –44.8)	<.001
Medical-surgical						
Without major teaching affiliation	491	–47.4 (–43.2 to –51.2)	<.001	25	–28.5 (–16.6 to –38.6)	<.001
With major teaching affiliation	211	–54.2 (–50.2 to –57.9)	<.001	10	–62.9 (–54.4 to –69.8)	<.001
Cardiothoracic	151	–38.4 (–30.2 to –45.8)	<.001	6	–6.6 (–33.9 to 31.5)	.70
Coronary	195	–38.2 (–29.4 to –45.9)	<.001	14	–39.6 (–20.4 to –54.3)	<.001
Pediatric	144	–38.5 (–32.1 to –44.3)	<.001	11	–31.3 (–17.1 to –43.2)	<.001

Abbreviations: CI, confidence interval; ICU, intensive care unit.

^aData are from the National Nosocomial Infection Surveillance (NNIS) system, 1997–2004; National Healthcare Safety Network (NHSN), 2006–2007. No 2005 data are available from either surveillance system.

^bChange in incidence is calculated as the relative change between the model-estimated annual incidence in 2007 compared with 1997.

^cData are restricted to ICUs reporting at least 50 central line days for at least 1 month in each of 10 surveillance years from 1997 through 2007 (no data for 2005).

^dThe substantial decline in the number of ICUs included in the subanalyses of trends in central line–associated bloodstream infection incidence for each ICU type is partly a result of the fact that NNIS facilities were not required to use the same names for their participating ICUs under NHSN. Therefore, some ICUs that reported data in all 10 surveillance years could not be linked by name for inclusion in the subanalyses presented in this table.

1990 through 1999²⁵ and are consistent with reports of successful prevention efforts by groups of health care facilities that have implemented programs designed to improve central line insertion and care practices.²⁶⁻²⁹ Other potential influences on MRSA central line–associated BSI incidence trends are dissemination of prevention guidelines and increasing success in preventing MRSA transmission between patients.^{18,30,31} However, the relative contributions of these and other factors to observed trends in MRSA and MSSA central line–associated BSI incidence are uncertain.

To our knowledge, no other recent US study has reported long-term trends in the incidence of MRSA central line–associated BSI in as large a number of adult ICUs as this one. Although our findings may suggest general improvement in preventing MRSA central line–associated BSI infections among ICU patients in participating health care facilities, these data do not account for other types of health care–associated MRSA infection or infections occurring in non-ICU or nonhospital populations, where the majority of the health care–associated MRSA burden is likely to exist.^{32,33} More information is needed to determine whether recent declines in MRSA central line–associated BSI incidence in ICU patients are indicative of trends in the incidence of MRSA disease in other patient populations and patient care areas. Such decreases have been evident in other developed countries with national health care–associated infection surveillance and prevention efforts.^{34,35}

Our analysis also demonstrates that reliance on percent MRSA (ie, pooled mean percent resistance) as the sole metric for monitoring the magnitude of the MRSA problem may be misleading. Percent MRSA is an expression of the likelihood that *S aureus* will be MRSA, but trends in percent MRSA may be discordant from trends in the absolute risk of MRSA disease as measured by MRSA incidence. Central line–associated BSI data aggregated across ICU types demonstrate discordance be-

tween trends in percent MRSA and MRSA incidence (Figure 1). The percent MRSA trend suggests a steady worsening of the MRSA central line–associated BSI problem over the full analysis period, whereas MRSA incidence data indicate a reversal of the direction of the MRSA central line–associated BSI problem occurring in 2001, with a subsequent dramatic decline resulting in a 2007 MRSA central line–associated BSI incidence rate significantly lower than that in 1997.

Similar discordance between trends in percent MRSA and MRSA incidence also was observed for several individual ICU types in which percent MRSA appeared to increase during time periods when MRSA incidence significantly declined (data not shown). These observations suggest that caution should be exercised when interpreting studies that report increasing percent MRSA among health care–associated infections without providing corresponding trend data for the incidence of MRSA infections. Percent MRSA is a vital metric for guiding empiric antimicrobial therapy when *S aureus* health care–associated infection is identified and may be useful for monitoring drug resistance in health care settings, but it should not be used as the sole measure of MRSA. Methicillin-resistant *S aureus* infection incidence is a more appropriate metric for monitoring the impact of interventions designed to decrease the risk of MRSA infection in the health care setting.

This trend analysis has some important limitations. First, although trends were analyzed longitudinally, the surveillance data used do not represent a consistent cohort of facilities followed over the entire analysis period, which raises the possibility that observed trends were influenced by migration of facilities into or out of the surveillance pool. However, the generally consistent trend results obtained in subanalyses limited to ICUs that participated in CDC surveillance in all 10 surveillance years suggest that sample migration does not explain the observed trends (Table 3). Second, the re-

sults may not be generalizable; although NNIS and NHSN hospitals are geographically dispersed, they are not strictly a representative sample of US hospitals.³⁶ Furthermore, participation in the surveillance process likely influences infection control efforts at these facilities and may influence central line–associated BSI risk.³⁷ Third, we were unable to assess the causes of the observed trends in central line–associated BSI incidence. Although subsets of NNIS facilities have participated in studies of prevention effectiveness,²⁶ the surveillance data used for this trend analysis do not include process measures linked to prevention efforts and do not allow us to test specific causation hypotheses.

Fourth, we also lacked specific data on changes in the mix of patients or patient care practices (such as the average duration of central line placement) in reporting ICUs, which could have influenced the observed trends. However, the stability of the 1 proxy measure for severity of patient illness and ICU practice that we were able to examine, central line device utilization ratio, suggests that changes in these factors during our analysis period were not dramatic. Fifth, although we took several steps to increase the comparability of data reported under NNIS and NHSN and confirmed that significant declines in MRSA central line–associated BSI incidence preceded the conclusion of data reporting under NNIS, we cannot exclude the possibility of artifacts in observed trends that are the result of the transition from one surveillance system to the other. Also as a result of the transition, we lacked data for the year 2005. Sixth, antimicrobial susceptibility testing was performed by laboratories servicing participating hospitals rather than by a central reference laboratory. However, in a 1999 study of antimicrobial testing proficiency among NNIS hospital laboratories, all 193 facilities participating in the study correctly identified the *S aureus* test strain as MRSA.³⁸ Lastly, we did not separately address trends for leading causes of central line–

associated BSI other than *S aureus*, such as coagulase-negative staphylococci, *Enterococcus* species, and *Candida* species, which have been associated with 34.1%, 16.0%, and 11.7%, respectively, of central line–associated BSIs reported to NHSN.³⁹ By comparison, MRSA and MSSA have been associated with 5.6% and 4.3%, respectively, of central line–associated BSIs reported to NHSN.³⁹

Concerns have been raised that the enactment of state laws requiring health care facilities to report rates of health care–associated infections to state agencies, the public, or both provides a disincentive for facilities to conduct thorough health care–associated infection surveillance and to accurately report health care–associated infections that are identified. The trend analysis presented in this article was not designed to examine the potential impact of public reporting laws on health care–associated infection, but it is unlikely that the observed trends in central line–associated BSI incidence can be explained by such impacts. Prior to the conclusion of health care–associated infection reporting to the CDC to NNIS at the end of 2004, only 2 states had implemented public reporting requirements relevant to central line–associated BSI that used clinical surveillance data (Pennsylvania passed legislation in November 2003, and Missouri passed legislation in June 2004).⁴⁰ Analysis of trends in aggregated MRSA central line–associated BSI incidence limited to NNIS data showed similar (and significant) declines either with (data presented in results) or without data from these 2 states included (data not shown).

In addition, a recent NHSN analysis found no significant differences in pooled mean central line–associated BSI rates with and without the inclusion of data from states that have required the use of NHSN for central line–associated BSI reporting.⁴¹ Nevertheless, as increasing numbers of states implement mandatory public reporting requirements for hospital-associated infections, evaluating the impact of such requirements on health care–associated

infection surveillance practices and reporting to NHSN will be critical.

CONCLUSIONS

In summary, MRSA central line–associated BSI incidence has declined in recent years in all major adult ICU types and has remained stable in pediatric ICUs. The overall decline in incidence stands in sharp contrast to trends in percent MRSA, which give an incomplete picture of changes in the magnitude of the MRSA problem over time and may have led to a misperception that the MRSA central line–associated BSI problem in ICUs has been increasing. Pervasive declines in the incidence rates of MSSA and total central line–associated BSI in all major non-neonatal ICU types also suggest that general central line–associated BSI prevention efforts are succeeding and may have contributed to the observed MRSA trends. Further study is needed to assess MRSA infection incidence in other patient populations and patient care areas and to determine the effect of specific prevention measures and of participation in national health care–associated infection surveillance on the observed trends.

Author Affiliations: Division of Healthcare Quality Promotion, Centers for Disease Control and Prevention, Atlanta, Georgia.

Author Contributions: Dr Burton had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Burton, Edwards, Horan, Fridkin.

Acquisition of data: Edwards, Horan.

Analysis and interpretation of data: Burton, Edwards, Horan, Jernigan, Fridkin.

Drafting of the manuscript: Burton, Edwards, Horan, Jernigan, Fridkin.

Critical revision of the manuscript for important intellectual content: Burton, Edwards, Horan, Jernigan, Fridkin.

Statistical analysis: Burton, Edwards.

Administrative, technical, or material support: Edwards, Horan, Jernigan.

Study supervision: Fridkin.

Financial Disclosures: None reported.

Funding/Support: No specific funding was provided for this analysis. The Division of Healthcare Quality Promotion, CDC, employed all authors of this article.

Role of the Sponsor: No commercial entity had any role in this work. The Division of Healthcare Quality Promotion, CDC, is responsible for the National Nosocomial Infections Surveillance System and the National Healthcare Safety Network and for managing the data submitted by participating health care facilities. The authors, not the agency, were solely responsible for the design and conduct of the study; analysis and interpretation of the data; and preparation, review, and approval of the manuscript.

Disclaimer: The findings and conclusions in this article are those of the authors and do not necessarily represent official views of the CDC.

Previous Presentations: Preliminary versions of data included in this manuscript were presented as abstracts at the 18th Annual Scientific Meeting of the Society for Healthcare Epidemiology of America (SHEA), Orlando, Florida, 2008.

Additional Contributions: We acknowledge the exceptional work of the infection control and hospital epidemiology staff performing surveillance as part of the National Nosocomial Infections Surveillance system and National Healthcare Safety Network.

REFERENCES

1. Bearman GM, Wenzel RP. Bacteremias: a leading cause of death. *Arch Med Res.* 2005;36(6):646-659.
2. Seybold U, Kourbatova EV, Johnson JG, et al. Emergence of community-associated methicillin-resistant *Staphylococcus aureus* USA300 genotype as a major cause of health care–associated blood stream infections. *Clin Infect Dis.* 2006;42(5):647-656.
3. Abramson MA, Sexton DJ. Nosocomial methicillin-resistant and methicillin-susceptible *Staphylococcus aureus* primary bacteremia: at what costs? *Infect Control Hosp Epidemiol.* 1999;20(6):408-411.
4. Crum NF, Lee RU, Thornton SA, et al. Fifteen-year study of the changing epidemiology of methicillin-resistant *Staphylococcus aureus*. *Am J Med.* 2006;119(11):943-951.
5. Cosgrove SE, Qi Y, Kaye KS, Harbarth S, Karchmer AW, Carmeli Y. The impact of methicillin resistance in *Staphylococcus aureus* bacteremia on patient outcomes: mortality, length of stay, and hospital charges. *Infect Control Hosp Epidemiol.* 2005;26(2):166-174.
6. Cosgrove SE, Sakoulas G, Perencevich EN, Schwaber MJ, Karchmer AW, Carmeli Y. Comparison of mortality associated with methicillin-resistant and methicillin-susceptible *Staphylococcus aureus* bacteremia: a meta-analysis. *Clin Infect Dis.* 2003;36(1):53-59.
7. Karchmer AW. Nosocomial bloodstream infections: organisms, risk factors, and implications. *Clin Infect Dis.* 2000;31(suppl 4):S139-S143.
8. Cimolai N. Methicillin-resistant *Staphylococcus aureus* public concern, and legislative mandates. *Infect Control Hosp Epidemiol.* 2007;28(7):896.
9. Weber SG, Huang SS, Oriola S, et al. Legislative mandates for use of active surveillance cultures to screen for methicillin-resistant *Staphylococcus aureus* and vancomycin-resistant enterococci: position statement from the Joint SHEA and APIC Task Force. *Am J Infect Control.* 2007;35(2):73-85.
10. Oztoprak N, Cevik MA, Akinci E, et al. Risk factors for ICU-acquired methicillin-resistant *Staphylococcus aureus* infections. *Am J Infect Control.* 2006;34(1):1-5.
11. Eggimann P, Pittet D. Infection control in the ICU. *Chest.* 2001;120(6):2059-2093.
12. Mermel LA. New technologies to prevent intravascular catheter-related bloodstream infections. *Emerg Infect Dis.* 2001;7(2):197-199.
13. Raad I, Hanna H. Intravascular catheters impregnated with antimicrobial agents: a milestone in the prevention of bloodstream infections. *Support Care Cancer.* 1999;7(6):386-390.
14. Gnass SA, Barboza L, Bilicich D, et al. Prevention of central venous catheter-related bloodstream infections using non-technologic strategies. *Infect Control Hosp Epidemiol.* 2004;25(8):675-677.
15. Centers for Disease Control and Prevention. Guidelines for the prevention of intravascular catheter-related infections. *Morb Mortal Wkly Rep MMWR.* 2002;51(RR-10):1-29.
16. Mermel LA. Prevention of central venous catheter-

related infections: what works other than impregnated or coated catheters? *J Hosp Infect*. 2007; 65(suppl 2):30-33.

17. Raad I, Hanna H, Maki D. Intravascular catheter-related infections: advances in diagnosis, prevention, and management. *Lancet Infect Dis*. 2007;7(10):645-657.

18. Muto CA, Jernigan JA, Ostrowsky BE, et al; SHEA. SHEA guideline for preventing nosocomial transmission of multidrug-resistant strains of *Staphylococcus aureus* and enterococcus. *Infect Control Hosp Epidemiol*. 2003;24(5):362-386.

19. Ben-David D, Mermel LA, Parenteau S. Methicillin-resistant *Staphylococcus aureus* transmission: the possible importance of unrecognized health care worker carriage. *Am J Infect Control*. 2008;36(2):93-97.

20. Centers for Disease Control and Prevention. The National Healthcare Safety Network (NHSN) Manual: Patient Safety Component Protocol. http://www.cdc.gov/ncidod/dhqp/pdf/nhsn/NHSN_Manual_PatientSafetyProtocol_CURRENT.pdf. Accessed July 31, 2008.

21. Horan TC, Gaynes RP. Surveillance of nosocomial infections. In: Mayhall CG, ed. *Hospital Epidemiology and Infection Control*. 3rd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2004:1659-1702.

22. Emori TG, Edwards JR, Culver DH, et al. Accuracy of reporting nosocomial infections in intensive-care-unit patients to the National Nosocomial Infections Surveillance System: a pilot study. *Infect Control Hosp Epidemiol*. 1998;19(5):308-316.

23. National Nosocomial Infections Surveillance (NNIS) System report, data summary from January 1990-May 1999, issued June 1999. *Am J Infect Control*. 1999; 27(6):520-532.

24. National Nosocomial Infections Surveillance System. National Nosocomial Infections Surveillance (NNIS) System Report, data summary from January 1992 through June 2004, issued October 2004. *Am J Infect Control*. 2004;32(8):470-485.

25. Centers for Disease Control and Prevention. Monitoring hospital-acquired infections to promote patient safety—United States, 1990-1999 [published correction appears in *MMWR Morb Mortal Wkly Rep*.

2000;49(9):189-190]. *MMWR Morb Mortal Wkly Rep*. 2000;49(8):149-153.

26. Centers for Disease Control and Prevention. Reduction in central line-associated bloodstream infections among patients in intensive care units—Pennsylvania, April 2001–March 2005. *MMWR Morb Mortal Wkly Rep*. 2005;54(40):1013-1016.

27. Pronovost P, Needham D, Berenholtz S, et al. An intervention to decrease catheter-related bloodstream infections in the ICU. *N Engl J Med*. 2006; 355(26):2725-2732.

28. Eggimann P, Harbarth S, Constantin MN, Touveneau S, Chevrolet JC, Pittet D. Impact of a prevention strategy targeted at vascular-access care on incidence of infections acquired in intensive care. *Lancet*. 2000;355(9218):1864-1868.

29. Warren DK, Cosgrove SE, Diekema DJ, et al; Prevention Epicenter Program. A multicenter intervention to prevent catheter-associated bloodstream infections. *Infect Control Hosp Epidemiol*. 2006; 27(7):662-669.

30. Boyce JM, Pittet D; Healthcare Infection Control Practices Advisory Committee; HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. Guideline for hand hygiene in health-care settings: recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. *Am J Infect Control*. 2002; 30(8):S1-S46.

31. Larson EL, Quiros D, Lin SX. Dissemination of the CDC's Hand Hygiene Guideline and impact on infection rates. *Am J Infect Control*. 2007;35(10):666-675.

32. Klevens RM, Morrison MA, Nadle J, et al; Active Bacterial Core surveillance (ABCs) MRSA Investigators. Invasive methicillin-resistant *Staphylococcus aureus* infections in the United States. *JAMA*. 2007;298 (15):1763-1771.

33. Klein E, Smith DL, Laxminarayan R. Hospitalizations and deaths caused by methicillin-resistant *Staphylococcus aureus*, United States, 1999-2005. *Emerg Infect Dis*. 2007;13(12):1840-1846.

34. UK Health Protection Agency Surveillance of Healthcare Associated Infections Report 2007. London, England: Healthcare Associated Infection & Antimicrobial Resistance Department, UK Health Protection Agency. http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1196942169446. Accessed July 31, 2008.

35. Meyer E, Schwab F, Gastmeier P, Jonas D, Rueden H, Daschner FD. Methicillin-resistant *Staphylococcus aureus* in German intensive care units during 2000-2003: data from Project SARI (Surveillance of Antimicrobial Use and Antimicrobial Resistance in Intensive Care Units). *Infect Control Hosp Epidemiol*. 2006; 27(2):146-154.

36. Richards C, Emori TG, Edwards J, Fridkin S, Tolson J, Gaynes R. Characteristics of hospitals and infection control professionals participating in the National Nosocomial Infections Surveillance System 1999. *Am J Infect Control*. 2001;29(6):400-403.

37. Gastmeier P, Geffers C, Brandt C, et al. Effectiveness of a nationwide nosocomial infection surveillance system for reducing nosocomial infections. *J Hosp Infect*. 2006;64(1):16-22.

38. Hageman JC, Fridkin SK, Mohammed JM, Steward CD, Gaynes RP, Tenover FC; National Nosocomial Infections Surveillance System Hospitals. Antimicrobial proficiency testing of National Nosocomial Infections Surveillance System hospital laboratories. *Infect Control Hosp Epidemiol*. 2003;24(5):356-361.

39. Hidron AI, Edwards JR, Patel J, et al; Participating National Healthcare Safety Network Facilities. NHSN annual update: antimicrobial-resistant pathogens associated with healthcare-associated infections: annual summary of data reported to the National Healthcare Safety Network at the Centers for Disease Control and Prevention, 2006-2007. *Infect Control Hosp Epidemiol*. 2008;29(11):996-1011.

40. Edmond MB, Bearman GM. Mandatory public reporting in the USA: an example to follow? *J Hosp Infect*. 2007;65(suppl 2):182-188.

41. Edwards JR, Peterson KD, Andrus ML, Dudeck MA, Pollock DA, Horan TC; National Healthcare Safety Network Facilities. National Healthcare Safety Network (NHSN) Report, data summary for 2006 through 2007, issued November 2008. *Am J Infect Control*. 2008;36(9):609-626.