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

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OBJECTIVE. To describe the frequency of selected antimicrobial resistance patterns among pathogens causing device-associated and procedure-associated healthcare-associated infections (HAIs) reported by hospitals in the National Healthcare Safety Network (NHSN).

METHODS. Data are included on HAIs (ie, central line–associated bloodstream infections, catheter-associated urinary tract infections, ventilator-associated pneumonia, and surgical site infections) reported to the Patient Safety Component of the NHSN between January 2006 and October 2007. The results of antimicrobial susceptibility testing of up to 3 pathogenic isolates per HAI by a hospital were evaluated to define antimicrobial-resistance in the pathogenic isolates. The pooled mean proportions of pathogenic isolates interpreted as resistant to selected antimicrobial agents were calculated by type of HAI and overall. The incidence rates of specific device-associated infections were calculated for selected antimicrobial-resistant pathogens according to type of patient care area; the variability in the reported rates is described.

RESULTS. Overall, 463 hospitals reported 1 or more HAIs: 412 (89%) were general acute care hospitals, and 309 (67%) had 200–1,000 beds. There were 28,502 HAIs reported among 25,384 patients. The 10 most common pathogens (accounting for 84% of any HAIs) were coagulase-negative staphylococci (15%), *Staphylococcus aureus* (15%), *Enterococcus* species (12%), *Candida* species (11%), *Escherichia coli* (10%), *Pseudomonas aeruginosa* (8%), *Klebsiella pneumoniae* (6%), *Enterobacter* species (5%), *Acinetobacter baumannii* (3%), and *Klebsiella oxytoca* (2%). The pooled mean proportion of pathogenic isolates resistant to antimicrobial agents varied significantly across types of HAI for some pathogen-antimicrobial combinations. As many as 16% of all HAIs were associated with the following multidrug-resistant pathogens: methicillin-resistant *S. aureus* (8% of HAIs), vancomycin-resistant *Enterococcus faecium* (4%), carbapenem-resistant *P. aeruginosa* (2%), extended-spectrum cephalosporin-resistant *K. pneumoniae* (1%), extended-spectrum cephalosporin-resistant *E. coli* (0.5%), and carbapenem-resistant *A. baumannii, K. pneumoniae, K. oxytoca,* and *E. coli* (0.5%). Nationwide, the majority of units reported no HAIs due to these antimicrobial-resistant pathogens.

Infect Control Hosp Epidemiol 2008; 29:996-1011

Antimicrobial-resistant pathogens that cause healthcare-associated infections (HAIs) pose an ongoing and increasing challenge to hospitals, both in the clinical treatment of patients and in the prevention of the cross-transmission of these problematic pathogens.[1-4] These pathogens include methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococcus* species, extended-spectrum β-lactamase–producing *Escherichia coli* and *Klebsiella* species, and fluoroquinolone- or carbapenem-resistant Enterobacteriaceae or *Pseudomonas aeruginosa*.[5-9] Describing the magnitude of the problem with respect to these antimicrobial-resistant pathogens is challenging, because the levels of antimicrobial resistance vary for different types of healthcare facilities and for different geographic areas, and some resistance phenotypes are difficult for laboratories to detect. However, the findings from such attempts may help the infection control and public health communities target problems and utilize resources more efficiently.

BACKGROUND

The National Healthcare Safety Network (NHSN) began collecting voluntarily reported data in 2005 as a national surveillance system for patient and healthcare personnel safety;

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Received May 1, 2008; accepted July 5, 2008; electronically published October 23, 2008.

 0899-823X/2008/2911-0002$15.00. DOI: 10.1086/591861

it is managed by the Division of Healthcare Quality Promotion at the Centers for Disease Control and Prevention. It integrates 3 former systems, the National Nosocomial Infections Surveillance (NNIS) system, the Dialysis Surveillance Network, and the National Surveillance System for Healthcare Workers, into a single system. In contrast to the NNIS system, the NHSN is designed to allow for surveillance of selected HAI data at locations other than intensive care units (ICUs), in hospitals and other types of healthcare facilities. Therefore, because of differences in the surveillance methodology of, and in the healthcare facilities reporting to, the NNIS system and the NHSN, the percentage of HAIs caused by antimicrobial-resistant pathogens reported to each system may not be comparable. A summary of device-associated infection rates reported to the NHSN has been published.[10] The purpose of this report is to describe the scope and magnitude of select antimicrobial-resistant pathogens among infections reported to the device- and procedure-associated modules of the NHSN.

METHODS

We analyzed data that hospitals reported from January 2006 through October 2007 to the device- and procedure-associated modules of the Patient Safety Component of the NHSN.[11] HAI data on postprocedure pneumonia were excluded from further analysis because they accounted for less than 1% of the infections reported during this time period.

NHSN Methodology

After completing NHSN training, healthcare facility personnel collect and report data on a monthly basis using standardized methods and definitions specific to the NHSN module(s) selected.[11] At least 6 months of data per year compliant with at least 1 module must be submitted to maintain active status in the NHSN.

For the device-associated module, patients in the selected patient care areas are monitored for 1–3 types of HAI: central line–associated bloodstream infection (CLABSI), catheter-associated urinary tract infection (CAUTI), or ventilator-associated pneumonia (VAP). Denominator data from the specific types of patient care areas are also collected. For the procedure-associated module, patients undergoing the selected surgical procedures are monitored for the development of either surgical site infection (SSI) or postprocedure pneumonia, or both. Procedure-specific denominator data are collected. HAIs are identified using standardized definitions that combine laboratory, clinical, and radiographic criteria, if applicable.[11]

Pathogens and Susceptibility Data

Microbiology data provided by the healthcare facility's designated clinical microbiology laboratory are collected for each HAI identified. The methods used for organism identification and antimicrobial susceptibility testing may vary between laboratories in different facilities. Up to 3 organisms per HAI were reported. Laboratories were expected to use Clinical and Laboratory Standards Institute standards for antimicrobial susceptibility testing;[12] data for each pathogenic isolate were reported to the NHSN using the following category interpretations: intermediate, resistant, susceptible, or not tested. In some cases, resistance was defined using data from a single antimicrobial test result (resistance to ceftazidime, amikacin, or cefepime in *P. aeruginosa* pathogenic isolates; resistance to oxacillin in *S. aureus* pathogenic isolates; and resistance to either vancomycin or ampicillin in *Enterococcus* pathogenic isolates). In other cases, because laboratories test different antimicrobial agents within a class of antibiotics, resistance was defined using data from at least one of several agents within the same antibiotic class. Specifically, we defined resistance as follows: for fluoroquinolone resistance among *P. aeruginosa* and *E. coli* pathogenic isolates, the organisms were resistant to either ciprofloxacin, levofloxacin, ofloxacin, or moxifloxacin; for piperacillin resistance among *P. aeruginosa* pathogenic isolates, the organisms were resistant to either piperacillin or piperacillin-tazobactam; for carbapenem resistance among *P. aeruginosa* and *Acinetobacter baumannii* pathogenic isolates, the organisms were resistant to imipenem or meropenem; for carbapenem resistance among *E. coli, Klebsiella pneumoniae,* and *Klebsiella oxytoca* pathogenic isolates, the organisms were resistant to imipenem, meropenem, or ertapenem; and for extended-spectrum cephalosporin resistance among *E. coli, K. pneumoniae, K. oxytoca,* and *A. baumannii* pathogenic isolates, the organisms were resistant to either ceftriaxone or ceftazidime. A subset of the organisms listed above were classified as multidrug resistant, including MRSA, vancomycin-resistant *Enterococcus,* extended-spectrum cephalosporin-resistant *K. pneumoniae* and *E. coli,* and carbapenem-resistant *P. aeruginosa, A. baumannii, K. pneumoniae, K. oxytoca,* and *E. coli.* This classification was based on the recognition that the mechanisms of resistance in these phenotypes confer resistance to multiple classes of antimicrobial agents.[12] This list is not all-inclusive but includes pathogens of epidemiologic concern.

Selection of Pathogen-Antimicrobial Combinations of Concern

Pathogen-antimicrobial combinations selected for evaluation in this report were chosen on the basis of their greater frequency, their higher degree of clinical importance, and consideration of emerging antimicrobial resistance. To describe the variability in the incidence rates of antimicrobial resistance among specific reporting patient care areas, 4 pathogen-antimicrobial combinations were selected for each type of device-associated HAI.

Statistical Analysis

Data were analyzed using SAS software, version 9.1 (SAS). For device-associated infections, the total number of HAIs

TABLE 1. Characteristics of Hospitals Reporting Antimicrobial-Resistant Healthcare-Associated Infections (HAIs) to the National Healthcare Safety Network, January 2006–October 2007

Characteristic	No. (%) of hospitals reporting ⩾1 HAI (n = 463)	No. (%) of HAIs reported (n = 28,502)
Type of hosptial		
Children's	16 (3.5)	1,060 (3.7)
General	412 (89.0)	26,767 (93.9)
Military	5 (1.1)	81 (0.3)
Veterans Affairs	20 (4.3)	510 (1.8)
Other[a]	10 (2.2)	84 (0.3)
Size of hospital		
⩽200 beds	151 (32.6)	2,270 (8.0)
200–500 beds	217 (46.9)	10,669 (37.4)
500–1,000 beds	92 (19.9)	15,079 (52.9)
⩾1,000 beds	3 (0.7)	484 (1.7)

[a] Oncology hospital, orthopedic hospital, women's and children's hospital, and women's hospital.

and their distribution by type of hospital, patient care area, and procedure were calculated. For procedure-associated infection, the total number of pathogens and their distribution by type of HAI and surgical procedure were calculated. For each type of HAI, the percentage of pathogenic isolates resistant to antimicrobial agents (hereafter, the resistance percentage) was calculated for the pathogen-antimicrobial combinations by pooling data from all NHSN hospitals for this time period (ie, the sum of pathogenic isolates that were found to be resistant divided by the sum of pathogenic isolates that were tested, multiplied by 100). If fewer than 30 isolates were tested for antimicrobial susceptibility overall, the data were considered of low accuracy and therefore not reported, consistent with Clinical and Laboratory Standards Institute recommendations.[13] The resistance percentage is reported by type of HAI. Additionally, if the resistance percentage did not differ between the types of device-associated infections for a specific pathogen-antimicrobial combination, a pooled device-associated resistance percentage was also reported. Differences in the resistance percentages were compared across types of HAI using the χ^2 test for independence (ie, comparing the lowest and highest resistance percentages for device-associated HAIs, and comparing the pooled device-associated HAI resistance percentages and SSI resistance percentages).

Location-specific incidence rates of HAI due to selected antimicrobial-resistant pathogens were also calculated for MRSA (CLABSI and VAP), vancomycin-resistant *Enterococcus faecium* (CLABSI and CAUTI), extended-spectrum cephalosporin-resistant *K. pneumoniae* (CLABSI, CAUTI, and VAP),

TABLE 2. Distribution of Device-Associated Healthcare-Associated Infections (HAIs) Reported to the National Healthcare Safety Network, January 2006–October 2007, Stratified by Type of Patient Care Area (PCA)

Type of PCA	No. of units reporting (n = 1,040[a])	No. (%) of HAIs			
		Overall	CLABSI	CAUTI	VAP
Burn ICU	18	690 (3.0)	271 (2.7)	206 (2.4)	213 (4.7)
Medical cardiac ICU	84	1,135 (4.9)	429 (4.3)	548 (6.4)	158 (3.5)
Cardiothoracic surgical ICU	76	1,299 (5.6)	443 (4.4)	469 (5.5)	387 (8.6)
MICU[b]	116	2,961 (12.8)	1,204 (12.0)	1,252 (14.6)	505 (11.2)
Medical-surgical ICU	268	5,260 (22.7)	1,918 (19.0)	2,208 (25.7)	1,134 (25.1)
Medical-surgical ward	31	1,116 (4.8)	288 (2.9)	827 (9.6)	1 (0.02)
NICU[c]	127	2,421 (10.5)	2,076 (20.6)	0 (0.00)	345 (7.6)
Neurosurgical ICU	31	867 (3.7)	268 (2.7)	398 (4.6)	201 (4.4)
PICU[d]	65	958 (4.1)	621 (6.2)	197 (2.3)	140 (3.1)
SCA[e]	25	631 (2.7)	552 (5.5)	65 (0.8)	14 (0.3)
SICU	100	2,730 (11.8)	1,031 (10.2)	1,005 (11.7)	694 (15.3)
Trauma ICU	27	1,520 (6.6)	448 (4.4)	495 (5.8)	577 (12.8)
Inpatient ward[f]	37	900 (3.9)	312 (3.1)	579 (6.7)	9 (0.2)
Other location	35	679 (2.9)	203 (2.0)	330 (3.9)	146 (3.2)
Total		23,167 (100)	10,064 (100)	8,579 (100)	4,524 (100)

NOTE. CAUTI, catheter-associated urinary tract infection; CLABSI, central line–associated bloodstream infection; ICU, intensive care unit; MICU, medical ICU; NICU, neonatal ICU; PICU, pediatric ICU; SCA, specialty care area; SICU, surgical ICU; VAP, ventilator-associated pneumonia.

[a] Data were collected from 1,428 PCAs overall, but only from 1,040 PCAs for device-associated HAIs.

[b] Includes prenatal and neurology ICUs

[c] Level II–III and level III NICUs.

[d] All types.

[e] Bone marrow transplant, inpatient acute dialysis, hematology and oncology, pediatric hematology and oncology, long-term acute care, solid organ transplant, and pediatric solid organ transplant.

[f] Other than SCAs and inpatient medical-surgical wards.

carbapenem-resistant *A. baumannii* (CLABSI, CAUTI, and VAP), and carbapenem-resistant *P. aeruginosa* (CAUTI and VAP). For these rates, only locations reporting more than 50 device-days were included in the calculations. Pooled mean incidence rates for specific patient care areas included data from all healthcare facilities reporting from those patient care areas. The range of incidence rates for a specific patient care area was reported only if more than 20 healthcare facilities reported data for that patient care area.

To estimate the effects of unique recognized antimicrobial resistance patterns reported from certain geographic areas, and state mandatory reporting requirements on data in the current pool, we attempted to determine the relative contribution of facilities from New York on the magnitude of resistance. This was done by comparing the pooled device-associated HAI resistance percentage while including and excluding data from New York facilities. We focused on data from this state because all New York hospitals were mandated to use the NHSN for reporting HAI data beginning January 2007 and because recent reports have described carbapenemase-producing *Klebsiella* species as a problem among some New York hospitals.[14]

RESULTS

Distribution of Infections

From January 2006 through October 2007, a total of 28,502 HAIs were reported to the NHSN: 10,064 (35.3%) were cases of CLABSI, 8,579 (30.1%) were cases of CAUTI, 4,524 (15.9%) were cases of VAP, 5,291 (18.6%) were cases of SSI, and 44 (0.2%) were cases of postprocedure pneumonia (data not shown). The 463 hospitals that reported 1 or more HAIs to the NHSN during this time period were predominantly large (Table 1): 412 (89%) were general acute care hospitals, 309 (67%) had between 200 and 1,000 beds, and 151 (33%) had less than 200 beds. Hospitals from 42 states were involved in the reporting to the NHSN. Most of the HAIs reported (19,390 [68%] of 28,502) were from hospitals in the northeastern and southern United States, which comprised 73% of the total number of hospitals.

Most patients with HAI were adults; 21,576 (85%) of the 25,384 patients were older than 20 years of age. Patients 0–3 years of age were mainly diagnosed with CLABSI (which represented 78% of HAIs for that age group). The HAIs were reported from 1,428 unique locations representing 10 general types of patient care areas within the 463 NHSN hospitals. Most device-associated HAIs were reported from ICUs: medical-surgical ICUs (23%), medical ICUs (13%), surgical ICUs (12%), neonatal ICUs (11%), trauma ICUs (7%), cardiothoracic surgical ICUs (6%), medical cardiac ICUs (5%), pediatric ICUs (4%), neurosurgical ICUs (4%), and burn ICUs (3%). The remaining 12% of device-associated HAIs were reported from specialty care areas (3%) and other inpatient non-ICU areas (ie, medical-surgical wards [5%] and other inpatient wards [4%]) (Table 2). The majority of procedure-associated HAIs were identified on inpatient surgical wards (data not shown), and most were associated with 1 of 4 major procedure types: cardiac surgery (29%), abdominal surgery (26%), orthopedic surgery (18%), and neurosurgery (12%) (Table 3).

Pathogen Distribution

From 28,502 cases of HAI, a total of 33,848 pathogenic isolates were recovered and reported: 29,448 (87%) were bacteria, and 4,400 (13%) were fungi (Table 4). Overall, 16.4% of infections were polymicrobial and varied slightly by type of HAI: 20% of cases of SSI were polymicrobial, 21% of cases of VAP, 11% of cases of CLABSI, and 8% of cases of CAUTI.

Overall, the majority of isolates (70%) were either coagulase-negative staphylococci (15%), *S. aureus* (15%), *Enterococcus* species (12%), *Candida* species (11%), *E. coli* (10%), or *P. aeruginosa* (8%) (Table 4). The rank-order distribution of the selected pathogens varied by type of HAI but did not vary significantly when stratified by patient care area or by criteria used to identify each HAI (except for cases of CLABSI, for which criterion 2 is specific for common skin contaminant; data not shown).[11] For cases of SSI, the distribution of pathogens varied only slightly when stratified by type of SSI (superficial incisional, deep incisional, or organ space; data not shown) but varied signficantly when stratified by type of

TABLE 3. Distribution of Procedure-Associated Healthcare-Associated Infections (HAIs) Reported to the National Healthcare Safety Network, January 2006–October 2007, Stratified by Type of Surgery

Type of surgery	No. of surgeries	No. (%) of HAIs		
		Overall	SSI	PPP
Abdominal[a]	1,389	1,390 (26.1)	1,377 (26.0)	13 (29.5)
Cardiac[b]	1,557	1557 (29.2)	1536 (29.0)	21 (47.7)
Neurological[c]	650	650 (12.2)	650 (12.3)	0 (0.0)
Ob/Gyn[d]	335	335 (6.3)	335 (6.3)	0 (0.0)
Orthopedic[e]	969	969 (18.2)	962 (18.2)	7 (15.9)
Transplant[f]	87	87 (1.6)	86 (1.6)	1 (2.3)
Vascular[g]	217	217 (4.1)	217 (4.1)	0 (0.0)
Other	130	130 (2.4)	128 (2.4)	2 (4.5)
Total		5,335 (100)	5,291 (100)	44 (100)

NOTE. Ob/Gyn, obstetrical and gynecological; PPP, postprocedure pneumonia; SSI, surgical site infection.

[a] Appendectomy, bile duct, liver, or pancreatic surgery, gallbladder surgery, colon surgery, gastric surgery, herniorrhaphy, small bowel surgery, spleen surgery, and exploratory laparotomy.

[b] Cardiac surgery, coronary artery bypass graft with chest incision with or without donor incision, and thoracic surgery.

[c] Craniotomy, spinal fusion, laminectomy, refusion of spine, and ventricular shunt.

[d] Abdominal hysterectomy, cesarean section, vaginal hysterectomy, and ovarian surgery.

[e] Open reduction internal fixation, hip prosthesis, and knee prosthesis.

[f] Heart, kidney, and liver transplants

[g] Abdominal aortic aneurysm repair, limb amputation, arteriovenous shunt for hemodialysis, carotid endarterectomy, and peripheral vascular bypass surgery.

TABLE 4. Distribution and Rank Order of Selected Pathogens Associated With Cases of Healthcare-Associated Infection (HAI) Reported to the National Healthcare Safety Network, January 2006–October 2007, by Type of HAI

	Overall[a]		CLABSI		CAUTI		VAP		SSI	
Pathogen	No. (%) of pathogenic isolates	Rank	No. (%) of pathogenic isolates	Rank	No. (%) of pathogenic isolates	Rank	No. (%) of pathogenic isolates	Rank	No. (%) of pathogenic isolates	Rank
CoNS	5,178 (15.3)	1	3,900 (34.1)	1	234 (2.5)	7	79 (1.3)	9	965 (13.7)	2
Staphylococcus aureus	4,913 (14.5)	2	1,127 (9.9)	4	208 (2.2)	8	1,456 (24.4)	1	2,108 (30.0)	1
Enterococcus species		3		2		3		10		3
E. faecalis	1,177 (3.5)		627 (5.5)		335 (3.6)		21 (0.4)		194 (2.8)	
E. faecium	1,888 (5.6)		942 (8.2)		562 (6.0)		38 (0.6)		345 (4.9)	
NOS	1,028 (3.0)		265 (2.3)		496 (5.3)		18 (0.3)		249 (3.5)	
Candida species		4		3		2		7		8
C. albicans	2,295 (6.8)		673 (5.9)		1,361 (14.5)		140 (2.4)		115 (1.6)	
Other *Candida* spp. or NOS	1,333 (3.9)		669 (5.9)		613 (6.5)		20 (0.3)		30 (0.4)	
Escherichia coli	3,264 (9.6)	5	310 (2.7)	8	2,009 (21.4)	1	271 (4.6)	6	671 (9.6)	4
Pseudomonas aeruginosa	2,664 (7.9)	6	357 (3.1)	7	938 (10.0)	4	972 (16.3)	2	390 (5.6)	5
Klebsiella pneumoniae	1,956 (5.8)	7	563 (4.9)	5	722 (7.7)	5	446 (7.5)	5	213 (3.0)	7
Enterobacter species	1,624 (4.8)	8	443 (3.9)	6	384 (4.1)	6	498 (8.4)	3	293 (4.2)	6
Acinetobacter baumannii	902 (2.7)	9	252 (2.2)	9	109 (1.2)	9	498 (8.4)	3	42 (0.6)	9
Klebsiella oxytoca	359 (1.1)	10	99 (0.9)	10	85 (0.9)	10	128 (2.2)	8	47 (0.7)	9
Other	5,267 (15.6)		1,201 (10.5)		1,321 (14.1)		1,375 (23.1)		1,363 (19.4)	
Total	33,848 (100)		11,428 (100)		9,377 (100)		5,960 (100)		7,025 (100)	

NOTE. Of the 28,502 cases of HAI reported, 4,671 (16.4%) were polymicrobial. CAUTI, catheter-associated urinary tract infection; CLABSI, central line–associated bloodstream infection; CoNS, coagulase-negative staphylococci; NOS, not otherwise specified; SSI, surgical site infection; VAP, ventilator-associated pneumonia.

[a] The overall total includes data for 58 pathogens associated with postprocedure pneumonia (not shown); the overall no. (%) of pathogenic isolates is dependent on the relative amount of data submitted for each type of HAI.

surgery (Table 5). Coagulase-negative staphylococci and *S. aureus* were the most prevalent pathogens causing SSI for most types of surgery, but gram-negative rods and enterococci were the more prevalent pathogens causing SSI following abdominal surgery. Enterococci were associated with approximately one-third of cases of SSI following transplant surgery.

Antimicrobial Resistance Percentages

Antimicrobial susceptibility testing data were received for most of the pathogenic isolates reported; the proportion of pathogenic isolates with test results varied by antimicrobial agent, pathogen, and type of HAI. The pathogen-antimicrobial combinations with the highest proportion of test results were as follows: *S. aureus* tested against oxacillin (97%–99.5%); *E. faecium* and *E. faecalis* tested against vancomycin (98.4%–99.5% and 91.9%–98.4%, respectively); and *P. aeruginosa* and *E. coli* tested against fluoroquinolones (91%–97.9% and 93.2%–95.6%, respectively). The pathogen-antimicrobial combinations with the lowest proportion of test results were associated with cases of CAUTI, specifically tested against carbapenems for *K. pneumoniae* (53.7%), *K. oxytoca* (44.7%), and *E. coli* (43.4%) (Tables 6 and 7). Pooled mean resistance percentages for the pathogen-antimicrobial combinations are shown in Tables 6 and 7.

For 13 of 22 antimicrobial-resistant phenotypes evaluated, the resistance percentage was comparable between all types of device-associated HAIs, and an overall pooled device-associated resistance percentage is presented (Table 6). However, there were some exceptions. Compared with cases of CAUTI, cases of CLABSI had a higher percentage of *Enterococcus* pathogenic isolates not otherwise specified that were resistant to vancomycin (18% vs 37%) and ampicillin (21.3% vs 40.7%), *P. aeruginosa* pathogenic isolates resistant to ceftazidime (12.6% vs 18.7%), and *K. pneumoniae* pathogenic isolates resistant to ceftriaxone or ceftazidime (21.2% vs 27.1%). Compared with cases of VAP, cases of CLABSI had a higher percentage of *E. coli* pathogenic isolates resistant to fluoroquinolones (22.7% vs 30.8%). Compared with cases of CLABSI and CAUTI, cases of VAP had a lower percentage of *K. pneumoniae* pathogenic isolates resistant to carbapenems (10.8% and 10.1% vs 3.6%). Compared with cases of CAUTI, cases of VAP had a higher percentage of *A. baumannii* pathogenic isolates resistant to carbapenems (25.6% vs 36.8%) and a higher percentage of *E. coli* pathogenic isolates resistant to ceftriaxone or ceftazidime (5.5% vs 11.0%). Compared with cases of CLABSI, cases of CAUTI had a higher percentage of *E. coli* pathogenic isolates resistant to carbapenems (0.9% vs 4.0%) (Table 6). The resistance percentages were lower for pathogenic isolates recovered from patients with SSI than for pathogenic isolates recovered from patients with device-associated HAI, and these data are presented separately (Table 7).

When evaluating the relative contribution of the New York hospitals to the pooled data, we found that the pooled re-

TABLE 5. Distribution of Selected Pathogens Associated With Cases of Surgical Site Infection Reported to the National Healthcare Safety Network, January 2006–October 2007, by Type of Surgery

Pathogen	Total no. of pathogenic isolates	No. (%) of pathogenic isolates, by type of surgery[a]							
		Abdominal (n = 1,376)	Cardiac (n = 1,536)	Neurological (n = 650)	Ob/Gyn (n = 335)	Orthopedic (n = 963)	Transplant (n = 86)	Vascular (n = 203)	Other (n = 142)
CoNS	965	135 (6.4)	423 (21.9)	123 (16.2)	59 (12.4)	173 (15.3)	8 (6.4)	24 (7.8)	20 (10.9)
Staphylococcus aureus	2,108	268 (12.7)	627 (32.5)	387 (50.9)	134 (28.3)	548 (48.6)	14 (11.2)	96 (31.3)	34 (18.5)
Enterococcus species									
E. faecalis	345	165 (7.8)	52 (2.7)	9 (1.2)	30 (6.3)	57 (5.1)	13 (10.4)	8 (2.6)	11 (6.0)
E. faecium	194	121 (5.7)	17 (0.9)	1 (0.1)	4 (0.8)	13 (1.2)	25 (20.0)	3 (1.0)	10 (5.4)
NOS	249	114 (5.4)	40 (2.1)	13 (1.7)	14 (3.0)	34 (3.0)	5 (4.0)	19 (6.2)	10 (5.4)
Candida species									
C. albicans	115	58 (2.7)	27 (1.4)	3 (0.4)	2 (0.4)	2 (0.2)	9 (7.2)	4 (1.3)	10 (5.4)
Other *Candida* spp. or NOS	30	9 (0.4)	10 (0.5)	0 (0.0)	0 (0.0)	2 (0.2)	4 (3.2)	3 (1.0)	2 (1.1)
Escherichia coli	671	395 (18.6)	116 (6.0)	28 (3.7)	45 (9.5)	34 (3.0)	11 (8.8)	26 (8.5)	16 (8.7)
Pseudomonas aeruginosa	390	129 (6.1)	136 (7.1)	32 (4.2)	15 (3.2)	38 (3.4)	3 (2.4)	27 (8.8)	10 (5.4)
Klebsiella pneumoniae	213	80 (3.8)	72 (3.7)	14 (1.8)	9 (1.9)	14 (1.2)	7 (5.6)	8 (2.6)	9 (4.9)
Enterobacter species	293	100 (4.7)	74 (3.8)	35 (4.6)	9 (1.9)	37 (3.3)	10 (8.0)	10 (3.3)	18 (9.8)
Acinetobacter baumannii	42	7 (0.3)	15 (0.8)	6 (0.8)	2 (0.4)	10 (0.9)	0 (0.0)	2 (0.7)	0 (0.0)
Klebsiella oxytoca	47	22 (1.0)	12 (0.6)	3 (0.4)	0 (0.0)	5 (0.4)	1 (0.8)	2 (0.7)	2 (1.1)
Total no. of pathogenic isolates[b]	7,025	2,118	1,929	760	474	1,128	125	307	184

NOTE. CoNS, coagulase-negative staphylococci; NOS, not otherwise specified; Ob/Gyn, obstetrical and gynecological.

[a] The types of surgery included for each catergory are as follows. Abdominal: appendectomy, bile duct, liver, or pancreatic surgery, gallbladder surgery, colon surgery, gastric surgery, herniorrhaphy, small bowel surgery, spleen, surgery, and exploratory laparotomy. Cardiac: cardiac surgery, coronary artery bypass graft with chest incision with or without donor incision, and thoracic surgery. Neurological: craniotomy, spinal fusion, laminectomy, refusion of spine, and ventricular shunt. Ob/Gyn: abdominal hysterectomy, cesarean section, vaginal hysterectomy, and ovarian surgery. Orthopedic: open reduction internal fixation, hip prosthesis, and knee prosthesis (data incomplete for procedures after October 2006, because procedures with implants require a full year of surveillance). Transplant: heart, kidney, and liver transplants (data incomplete for procedures after October 2006, because procedures with implants require a full year of surveillance). Vascular: abdominal aortic aneurysm repair, limb amputation, arteriovenous shunt for hemodialysis, carotid endarterectomy, and peripheral vascular bypass surgery.

[b] No. of pathogenic isolates reported per type of surgery.

sistance percentage for pathogen-antimicrobial combinations for all device-associated HAIs combined remained unchanged when healthcare facilities reporting from New York were excluded, with the exception of carbapenem-resistant *K. pneumoniae* pathogenic isolates, which changed from 8.7% to 5 % ($P < .001$). Because the exclusion of the New York hospitals did not affect the overall results reported, all of the tables include the data from New York.

Variability in the Incidence of HAIs With Select Antimicrobial-Resistant Pathogens

The pooled mean rates of infection with antimicrobial-resistant pathogens varied by type of patient care area for cases of CLABSI, CAUTI, and VAP, and these rates are reported separately (Tables 8–10). Data presented are limited to the more common antimicrobial-resistant pathogens, including some of the multidrug-resistant phenotypes; overall, the infection rate was very low. Also, in most cases, the majority of hospitals reported no antimicrobial-resistant HAIs (ie, the median rate was zero). For example, the median rate of MRSA CLABSI and of MRSA VAP was zero in all types of patient care areas, with the exception of MRSA VAP in trauma ICU and medical ICU (Tables 8 and 10). However, differences in the pooled mean rates were clearly evident by type of patient care area. For example, the rate of MRSA CLABSI (calculated as cases per 1,000 device-days) was low for inpatient medical-surgical wards and was average for other ICUs (cardiac, medical, surgical, and trauma ICUs) and inpatient medical wards. The highest MRSA CLABSI rate was reported by burn ICUs (0.93 cases per 1,000 device-days).

For antimicrobial-resistant gram-negative rods causing CLABSI, CAUTI, and VAP, in almost all types of patient care areas, approximately 80% of units or more reported no cases of carbapenem-resistant *A. baumannii* or extended-spectrum cephalosporin-resistant *K. pneumoniae* (Tables 8–10). In all types of patient care areas, 70% of units or more reported no cases of carbapenem-resistant *P. aeruginosa* CAUTI or VAP (Tables 9 and 10).

DISCUSSION

This is the first antimicrobial resistance report from the NHSN. We found the pathogen distribution still closely parallels that of the NNIS reports from 1986 to 1999.[15,16] The resistance percentages differ only slightly from the percentages found in historical data on ICU infections reported to the NNIS from 1986 to 2003.[15-18] Compared with the historical NNIS reports, this NHSN report found a slightly lower re-

TABLE 6. Antimicrobial Resistance Percentages for Pathogenic Isolates (n = 26,765) Associated With Cases of Device-Associated Healthcare-Associated Infection (HAI) Reported to the National Healthcare Safety Network, January 2006–October 2007

	CLABSI			CAUTI			VAP			Pooled[a]		
Pathogen, antimicrobial	No. of pathogenic isolates reported	No. (%) of pathogenic isolates tested	Resistance percentage, %[b]	No. of pathogenic isolates reported	No. (%) of pathogenic isolates tested	Resistance percentage, %[b]	No. of pathogenic isolates reported	No. (%) of pathogenic isolates tested	Resistance percentage, %[b]	No. of pathogenic isolates reported	No. (%) of pathogenic isolates tested	Resistance percentage, %[b]
Staphylococcus aureus	1,127			208			1,456			2,791		
OXA		1,103 (97.9)	56.8		207 (99.5)	65.2		1,426 (97.9)	54.4		2,736 (98.0)	56.2
Enterococcus species												
E. faecium	627			335			21			983		
VAN		617 (98.4)	78.9		331 (98.8)	81.0		NR	NR		969 (98.6)	80.0
AMP		547 (87.2)	90.5		278 (83.0)	89.9		NR	NR		845 (86.0)	90.4
E. faecalis	942			562			38			1,542		
VAN		909 (96.5)	7.5		553 (98.4)	6.1		35 (92.1)	2.9		1,497 (97.1)	6.9
AMP		813 (86.3)	4.2		481 (85.6)	3.1		34 (89.5)	2.9		1,328 (86.1)	3.8
NOS	265			496						…		
VAN		219 (82.6)	37.0		401 (80.8)	18.0	18	NR	NR		…	…
AMP		172 (64.9)	40.7		267 (53.8)	21.3		NR	NR		…	…
All	1,834			1,393			77			3,304		
VAN		1,745 (95.1)	36.4		1,285 (92.2)	29.1		67 (87.0)	32.8		3,097 (93.7)	33.3
Pseudomonas aeruginosa	357			938			972			2,267		
FQs		325 (91.0)	30.5		918 (97.9)	33.8		942 (96.9)	27.8		2,185 (96.4)	30.7
PIP or PTZ		242 (67.8)	20.2		609 (64.9)	17.1		694 (71.4)	17.0		1545 (68.2)	17.5
AMK		234 (65.5)	4.3		580 (61.8)	7.9		630 (64.8)	4.9		1,444 (63.7)	6.0
IMI or MERO		270 (75.6)	23.0		609 (64.9)	25.1		679 (69.9)	26.4		1,558 (68.7)	25.3
TAZ		289 (81.0)	18.7		745 (79.4)	12.6		755 (77.7)	13.1			
CPM		247 (69.2)	12.6		639 (68.1)	10.8		718 (73.9)	11.1		1604 (70.8)	11.2
Klebsiella pneumoniae	563			722			446			…		
CTR or TAZ		483 (85.8)	27.1		579 (80.2)	21.2		329 (73.8)	23.7		…	…
IMI, MERO, or ETP		452 (80.3)	10.8		388 (53.7)	10.1		302 (67.7)	3.6		…	…
Klebsiella oxytoca	99			85			128			312		
CTR or TAZ		82 (82.8)	15.9		68 (80.0)	17.6		82 (64.1)	17.1		232 (74.4)	16.8
IMI, MERO, or ETP		63 (63.6)	0.0		38 (44.7)	2.6		80 (62.5)	5.0		181 (58.0)	2.8
Acinetobacter baumannii	252			109			498			…		
IMI or MERO		219 (86.9)	29.2		82 (75.2)	25.6		427 (85.7)	36.8		…	…
Escherichia coli	310			2,009			271			…		
CTR or TAZ		258 (83.2)	8.1		1,577 (78.5)	5.5		173 (63.8)	11.0		…	…
IMI, MERO, or ETP		226 (72.9)	0.9		871 (43.4)	4.0		163 (60.1)	1.8		…	…
FQs		289 (93.2)	30.8		1,920 (95.6)	24.8		255 (94.1)	22.7		…	…

NOTE. AMK, amikacin; AMP, ampicillin; CAUTI, catheter-associated urinary tract infection; CLABSI, central line–associated bloodstream infection; CPM, cefepime; CTR, ceftriaxone; ETP, ertapenem; FQs, fluoroquinolones (ciprofloxacin, levofloxacin, moxifloxacin, or ofloxacin); IMI, imipenem; MERO, meropenem; NOS, not otherwise specified; NR, not reported (because <30 pathogenic isolates were tested); OXA, oxacillin; PIP, piperacillin; PTZ, piperacillin-tazobactam; TAZ, ceftazidime; VAN, vancomycin; VAP, ventilator-associated pneumonia.

[a] Some of the pooled percentages were significantly different ($P < .05$) and, therefore, were not pooled across types of HAI.

[b] Percentage of pathogenic isolates tested that were resistant.

TABLE 7. Antimicrobial Resistance Percentages for Pathogenic Isolates (n = 7,025) Associated With Cases of Surgical Site Infection Reported to the National Healthcare Safety Network, January 2006–October 2007

Pathogen, antimicrobial	No. of pathogenic isolates reported	No. (%) of pathogenic isolates tested	No. (%) of pathogenic isolates resistant[a]
Staphylococcus aureus	2,108		
OXA		2,045 (97.0)	1,006 (49.2)
Enterococcus species			
E. faecium	194		
VAN		193 (99.5)	109 (56.5)
AMP		169 (87.1)	120 (71.0)
E. faecalis	345		
VAN		317 (91.9)	15 (4.7)
AMP		291 (84.3)	12 (4.1)
NOS	249		
VAN		179 (71.9)	12 (6.7)
AMP		175 (70.3)	19 (10.9)
All	788		
VAN		689 (87.4)	136 (19.7)
Pseudomonas aeruginosa	390		
FQs		377 (96.7)	60 (15.9)
PIP or PTZ		262 (74.9)	23 (7.9)
AMK		196 (50.3)	4 (2.0)
IMI or MERO		279 (71.5)	33 (11.8)
TAZ		313 (80.3)	23 (7.3)
CPM		261 (66.9)	15 (5.7)
Klebsiella pneumoniae	213		
CTR or TAZ		162 (76.1)	24 (14.8)
IMI, MERO, or ETP		153 (71.8)	8 (5.2)
Klebsiella oxytoca	47		
CTR or TAZ		37 (78.7)	3 (8.1)
IMI, MERO, or ETP		NR	NR
Acinetobacter baumannii	42		
IMI or MERO		36 (85.7)	11 (30.6)
Escherichia coli	671		
CTR or TAZ		489 (72.9)	26 (5.3)
IMI, MERO, or ETP		439 (65.4)	11 (2.5)
FQs		629 (93.7)	143 (22.7)

NOTE. AMK, amikacin; AMP, ampicillin; CPM, cefepime; CTR, ceftriaxone; ETP, ertapenem; FQs, fluoroquinolones (ciprofloxacin, levofloxacin, moxifloxacin, or ofloxacin); IMI, imipenem; MERO, meropenem; NOS, not otherwise specified; NR, not reported (because <30 pathogenic isolates were tested); OXA, oxacillin; PIP, piperacillin; PTZ, piperacillin-tazobactam; TAZ, ceftazidime; VAN, vancomycin.

[a] No. (%) of pathogenic isolates tested that were resistant.

sistance percentage among device-associated HAIs for MRSA (60% vs 56% of pathogenic isolates)[17] and for extended-spectrum cephalosporin-resistant *P. aeruginosa* (32% vs 13%–19% of pathogenic isolates), but a slightly higher resistance percentage for vancomycin-resistant *Enterococcus* (29% vs 33% of pathogenic isolates), extended-spectrum cephalosporin-resistant *E. coli* (6% vs 6%–11% of pathogenic isolates), extended-spectrum cephalosporin-resistant *K. pneumoniae* (21% vs 21%–27% of pathogenic isolates), and carbapenem-resistant *P. aeruginosa* (21% vs 25% of pathogenic isolates).[18] These current patterns seem to be similar to those found in national and international surveillance studies.[19-23]

For device-associated infections and SSIs, the most prevalent organisms overall were gram-positive cocci (*S. aureus*, enterococci, and coagulase-negative staphylococci, which were associated with 40% of infections) and *Candida* species. For cases of CLABSI, CAUTI, and VAP, the ranking of the 4 most common pathogens is almost identical to that of the NNIS report published in 1999.[15] One notable exception is for VAP; *A. baumannii* now equals *Enterobacter* species, as the third most common pathogen. In contrast, the ranking of pathogens for ICU-associated HAIs from European studies reveals a greater contribution from *E. coli* and *Pseudomonas* species and a less prominent contribution from *Enterococcus* species[22,23] and, in some cases, *Candida* species.[22] These differences may be explained by the use of different surveillance methods (the NHSN limits reports to device- and procedure-associated infections based on specific criteria, whereas other institutions may use any positive clinical culture result, which may represent either colonization or infection) or perhaps by geographic differences.

Overall, compared with studies from other surveillance systems involving ICUs from European and North American countries (including the United States), our pooled mean resistance percentages are similar for MRSA and, in some instances, for *P. aeruginosa*, but are higher for most other pathogens.[9,19-25] For MRSA pathogenic isolates, resistance percentages as low as 20% have been reported from Canada[21] and as high as 80% from southern European countries,[23] but resistance percentages from ICUs in Europe and North America are comparable to ours (50%–60% of pathogenic isolates).[19,20,23] For *Enterococcus* species, the percentages of resistance to vancomycin that we found are higher overall than those from Europe and North America (33% vs 13%–28% of pathogenic isolates),[19,20,24,25] as are the percentages we found for vancomycin-resistant *E. faecium* pathogenic isolates (80% vs 0.8% reported from France and 24% from Italy).[21] For the *P. aeruginosa* pathogenic isolates tested, the pooled mean resistance percentages for most antimicrobials were comparable with those of other studies in general,[9,19-21,23-26] except for Italy, where a higher percentage of resistance to ceftazidime, cefepime, piperacillin, and fluoroquinolone has been reported.[21] However, the carbapenem resistance percentage was higher overall in this NHSN report.[9,19,20,22,23]

Among Enterobacteriaceae pathogenic isolates, resistance to fluoroquinolones, extended-spectrum cephalosporins, and carbapenems was generally higher in our report, compared with other isolate-based testing systems both inside and outside the United States.[9,19-22,24,25] Among these reports, the notable exceptions included the higher percentage of extended-spectrum cephalosporin resistance among *K. pneumoniae* (29% of pathogenic isolates) and *K. oxytoca* (15% of pathogenic isolates) from Italy.[21] Also of note, no carbapenem-resistant *K. oxytoca* pathogenic isolates were reported from

TABLE 8. Rates of Central Line–Associated Bloodstream Infection (CLABSI) Caused by Selected Antimicrobial-Resistant Pathogens Reported to the National Healthcare Safety Network, January 2006–October 2007, by Type of Patient Care Area (PCA)

Pathogen, type of PCA[a]	No. of units reporting	No. of months reported	No. of cases of infection	No. of device-days	No. of infections per 1,000 device-days				Percentage of units reporting no resistant cases
					Pooled mean	Median	75th percentile	90th percentile	
MRSA									
Burn ICU	19	259	32	34,546	0.93	NR	NR	NR	52.6
Medical cardiac ICU	110	1,260	38	142,180	0.27	0.00	0.25	0.97	72.7
Cardiothoracic surgical ICU	90	1,128	23	217,256	0.11	0.00	0.00	0.32	83.3
MICU	134	1,622	72	365,378	0.20	0.00	0.24	0.55	69.4
Medical-surgical ICU									
Major teaching	100	1,266	50	258,460	0.19	0.00	0.30	0.52	64.0
All others	296	2,928	63	491,709	0.13	0.00	0.00	0.40	83.8
Neurosurgical ICU	36	405	9	55,473	0.16	0.00	0.00	0.45	83.3
PICU	72	898	16	111,087	0.14	0.00	0.00	0.39	83.3
SICU	118	1,579	65	311,761	0.21	0.00	0.27	0.59	70.3
Trauma ICU	31	361	25	83,479	0.30	0.00	0.46	0.60	58.1
Inpatient medical ward	29	289	13	46,349	0.28	0.00	0.17	1.05	72.4
Inpatient medical-surgical ward	57	543	19	105,972	0.18	0.00	0.00	0.94	75.4
Vanco-res *E. faecium*									
Burn ICU	19	259	2	34,546	0.06	NR	NR	NR	NR
Medical cardiac ICU	110	1,260	26	142,180	0.18	0.00	0.00	0.70	84.5
Cardiothoracic surgical ICU	90	1,128	14	217,256	0.06	0.00	0.00	0.23	85.6
MICU	134	1,622	135	365,378	0.37	0.00	0.57	1.08	58.2
Medical-surgical ICU									
Major teaching	100	1,266	46	258,460	0.18	0.00	0.15	0.62	74.0
All others	296	2,928	64	491,709	0.13	0.00	0.00	0.27	86.8
Neurosurgical ICU	36	405	5	55,473	0.09	0.00	0.00	0.47	86.1
PICU	72	898	16	111,087	0.14	0.00	0.00	0.41	81.9
SICU	118	1,579	45	311,761	0.14	0.00	0.08	0.49	74.6
Trauma ICU	31	361	12	83,479	0.14	0.00	0.18	0.40	71.0
Inpatient medical ward	29	289	7	46,349	0.15	0.00	0.00	0.00	93.1
Inpatient medical-surgical ward	57	543	14	105,972	0.13	0.00	0.00	0.20	87.7

Carbp-res *A. baumannii*									
Burn ICU	19	259	12	34,546	0.35	NR	NR	NR	NR
Medical cardiac ICU	110	1,260	1	142,180	0.01	0.00	0.00	0.00	99.1
Cardiothoracic surgical ICU	90	1,128	0	217,256	0.00	0.00	0.00	0.00	100.0
MICU	134	1,622	20	365,378	0.05	0.00	0.00	0.00	90.3
Medical-surgical ICU									
Major teaching	100	1,266	7	258,460	0.03	0.00	0.00	0.00	95.0
All others	296	2,928	5	491,709	0.01	0.00	0.00	0.00	98.3
Neurosurgical ICU	36	405	1	55,473	0.02	0.00	0.00	0.00	97.2
PICU	72	898	1	111,087	0.01	0.00	0.00	0.00	98.6
SICU	118	1,579	8	311,761	0.03	0.00	0.00	0.00	94.1
Trauma ICU	31	361	1	83,479	0.01	0.00	0.00	0.00	96.8
Inpatient medical ward	29	289	1	46,349	0.02	0.00	0.00	0.00	96.6
Inpatient medical-surgical ward	57	543	0	105,972	0.00	0.00	0.00	0.00	100.0
ES-Ceph–res *K. pneumoniae*[b]									
Burn ICU	19	259	9	34,546	0.26	NR	NR	NR	NR
Medical cardiac ICU	110	1,260	14	142,180	0.20	0.00	0.00	0.25	89.1
Cardiothoracic surgical ICU	90	1,128	3	217,256	0.01	0.00	0.00	0.00	97.8
MICU	134	1,622	31	365,378	0.08	0.00	0.00	0.32	84.3
Medical-surgical ICU									
Major teaching	100	1,266	11	258,460	0.04	0.00	0.00	0.00	91.0
All others	296	2,928	17	491,709	0.03	0.00	0.00	0.00	96.3
Neurosurgical ICU	36	405	4	55,473	0.07	0.00	0.00	0.34	88.9
PICU	72	898	5	111,087	0.05	0.00	0.00	0.00	93.1
SICU	118	1,579	14	311,761	0.04	0.00	0.00	0.00	92.4
Trauma ICU	31	361	1	83,479	0.01	0.00	0.00	0.00	96.8
Inpatient medical ward	29	289	3	46,349	0.06	0.00	0.00	0.00	93.1
Inpatient medical-surgical ward	57	543	2	105,972	0.02	0.00	0.00	0.00	96.5

NOTE. Carbp-res *A. baumannii,* carbapenem-resistant *Acinetobacter baumannii*; ES-Ceph–res *K. pneumoniae,* extended-spectrum cephalosporin-resistant *Klebsiella pneumoniae*; ICU, intensive care unit; MICU, medical ICU; MRSA, methicillin-resistant *Staphylococcus aureus*; NR, not reported (percentiles are not reported if <20 units of a specific type of PCA reported data); PICU, pediatric ICU; SICU, surgical ICU; Vanco-res *E. faecium,* vancomycin-resistant *Enterococcus faecium.*

[a] Includes PCAs with >50 device-days reported.

[b] Resistant to ceftriaxone or ceftazidime.

TABLE 9. Rates of Catheter-Associated Urinary Tract Infection (CAUTI) Caused by Selected Antimicrobial-Resistant Pathogens Reported to the National Healthcare Safety Network, January 2006–October 2007, by Type of Patient Care Area (PCA)

Pathogen, type of PCA[a]	No. of units reporting	No. of months reported	No. of cases of infection	No. of device-days	No. of infections per 1,000 device-days				Percentage of units reporting no resistant cases
					Pooled mean	Median	75th percentile	90th percentile	
Vanco-res *E. faecium*									
Burn ICU	14	171	3	22,977	0.13	NR	NR	NR	NR
Medical cardiac ICU	54	731	14	119,876	0.12	0.00	0.00	0.50	83.3
Cardiothoracic surgical ICU	46	680	11	128,736	0.09	0.00	0.00	0.29	84.8
MICU	66	955	68	285,497	0.24	0.00	0.37	0.76	59.1
Medical-surgical ICU									
Major Teaching	56	838	33	232,717	0.14	0.00	0.26	0.54	62.5
All others	116	1,465	38	410,147	0.09	0.00	0.00	0.42	79.3
Neurosurgical ICU	19	237	3	59,236	0.05	NR	NR	NR	NR
PICU	33	481	3	37,071	0.08	0.00	0.00	0.00	90.9
SICU	63	971	35	244,704	0.14	0.00	0.20	0.45	68.3
Trauma ICU	20	272	16	86,948	0.18	0.00	0.24	0.81	55.0
Inpatient medical ward	17	169	14	31,189	0.45	NR	NR	NR	NR
Inpatient medical-surgical ward	38	346	6	49,944	0.12	0.00	0.00	0.48	86.8
Carbp-res *P. aeruginosa*									
Burn ICU	14	171	16	22,977	0.70	NR	NR	NR	NR
Medical cardiac ICU	54	731	6	119,876	0.05	0.00	0.00	0.00	92.6
Cardiothoracic surgical ICU	46	680	11	128,736	0.09	0.00	0.00	0.28	78.3
MICU	66	955	21	285,497	0.07	0.00	0.00	0.27	80.3
Medical-surgical ICU									
Major teaching	56	838	12	232,717	0.05	0.00	0.00	0.20	85.7
All others	116	1,465	7	410,147	0.02	0.00	0.00	0.00	94.0
Neurosurgical ICU	19	237	5	59,236	0.08	NR	NR	NR	NR
PICU	33	481	3	37,071	0.08	0.00	0.00	0.00	90.9
SICU	63	971	25	244,704	0.10	0.00	0.00	0.22	76.2
Trauma ICU	20	272	9	86,948	0.10	0.00	0.18	0.47	75.0
Inpatient medical ward	17	169	3	31,189	0.10	NR	NR	NR	NR
Inpatient medical-surgical ward	38	346	4	49,944	0.08	0.00	0.00	0.00	94.7

Carbp-res *A. baumannii*									
Burn ICU	14	171	2	22,977	0.09	NR	NR	NR	NR
Medical cardiac ICU	54	731	0	119,876	0.00	0.00	0.00	0.00	100.0
Cardiothoracic surgical ICU	46	680	1	128,736	0.01	0.00	0.00	0.00	97.8
MICU	66	955	5	285,497	0.02	0.00	0.00	0.00	92.4
Medical-surgical ICU									
Major teaching	56	838	1	232,717	0.00	0.00	0.00	0.00	98.2
All others	116	1,465	1	410,147	0.00	0.00	0.00	0.00	99.1
Neurosurgical ICU	19	237	1	59,236	0.02	NR	NR	NR	NR
PICU	33	481	1	37,071	0.03	0.00	0.00	0.00	97.0
SICU	63	971	2	244,704	0.01	0.00	0.00	0.00	96.8
Trauma ICU	20	272	2	86,948	0.02	0.00	0.00	0.00	95.0
Inpatient medical ward	17	169	0	31,189	0.00	NR	NR	NR	NR
Inpatient medical-surgical ward	38	346	1	49,944	0.02	0.00	0.00	0.00	97.4
ES-Ceph–res *K. pneumoniae*[b]									
Burn ICU	14	171	7	22,977	0.30	NR	NR	NR	NR
Medical cardiac ICU	54	731	10	119,876	0.08	0.00	0.00	0.22	88.9
Cardiothoracic surgical ICU	46	680	6	128,736	0.05	0.00	0.00	0.16	89.1
MICU	66	955	29	285,497	0.10	0.00	0.00	0.55	75.8
Medical-surgical ICU									
Major teaching	56	838	12	232,717	0.05	0.00	0.00	0.16	87.5
All others	116	1,465	13	410,147	0.03	0.00	0.00	0.00	93.1
Neurosurgical ICU	19	237	3	59,236	0.05	NR	NR	NR	NR
PICU	33	481	1	37,071	0.03	0.00	0.00	0.00	97.0
SICU	63	971	23	244,704	0.09	0.00	0.00	0.35	82.5
Trauma ICU	20	272	0	86,948	0.00	0.00	0.00	0.00	100.0
Inpatient medical ward	17	169	1	31,189	0.03	NR	NR	NR	NR
Inpatient medical-surgical ward	38	346	0	49,944	0.00	0.00	0.00	0.00	100.0

NOTE. Carbp-res *A. baumannii,* carbapenem-resistant *Acinetobacter baumannii*; Carbp-res *P. aeruginosa,* carbapenem-resistant *Pseudomonas aeruginosa*; ES-Ceph–res *K. pneumoniae,* extended-spectrum cephalosporin-resistant *Klebsiella pneumoniae*; ICU, intensive care unit; MICU, medical ICU; NR, not reported (percentiles are not reported if <20 units of a specific type of PCA reported data); PICU, pediatric ICU; SICU, surgical ICU.

[a] Includes PCAs with >50 device-days reported.

[b] Resistant to ceftriaxone or ceftazidime.

TABLE 10. Rates of Ventilator-Associated Pneumonia (VAP) Caused by Selected Antimicrobial-Resistant Pathogens Reported to the National Healthcare Safety Network, January 2006–October 2007, by Type of Patient Care Area (PCA)

Pathogen, type of PCA[a]	No. of units reporting	No. of months reported	No. of cases of infection	No. of device-days	No. of infections per 1,000 device-days				Percentage of units reporting no resistant cases
					Pooled mean	Median	75th percentile	90th percentile	
MRSA									
Burn ICU	16	208	52	18,683	0.56	NR	NR	NR	NR
Medical cardiac ICU	66	880	30	69,413	0.43	0.00	0.35	1.68	74.2
Cardiothoracic surgical ICU	64	902	50	90,696	0.55	0.00	0.47	1.73	71.9
MICU	84	1,160	106	209,885	0.51	0.10	0.71	1.57	48.8
Medical-surgical ICU									
Major teaching	72	975	92	155,178	0.59	0.00	0.97	2.01	52.8
All others	149	1,928	125	264,805	0.47	0.00	0.59	1.67	61.7
Neurosurgical ICU	25	287	36	33,468	1.08	0.00	1.10	2.90	60.0
PICU	43	602	11	64,413	0.17	0.00	0.00	0.60	81.4
SICU	81	1,163	112	148,455	0.75	0.00	0.68	1.51	55.6
Trauma ICU	24	301	84	61,714	1.36	0.59	1.63	2.89	37.5
Carbp-res *P. aeruginosa*									
Burn ICU	16	208	10	18,683	0.54	NR	NR	NR	NR
Medical cardiac ICU	66	880	9	69,413	0.13	0.00	0.00	0.00	92.4
Cardiothoracic surgical ICU	64	902	4	90,696	0.04	0.00	0.00	0.00	93.8
MICU	84	1,160	44	209,885	0.21	0.00	0.21	0.78	70.2
Medical-surgical ICU									
Major teaching	72	975	17	155,178	0.11	0.00	0.00	0.35	81.9
All others	149	1,928	15	264,805	0.06	0.00	0.00	0.00	90.6
Neurosurgical ICU	25	287	3	33,468	0.09	0.00	0.00	0.26	88.0
PICU	43	602	1	64,413	0.02	0.00	0.00	0.00	97.7
SICU	81	1,163	27	148,455	0.18	0.00	0.00	0.54	81.5
Trauma ICU	24	301	9	61,714	0.15	0.00	0.08	0.37	75.0
Carbp-res *A. baumannii*									
Burn ICU	16	208	33	18,683	1.77	NR	NR	NR	NR

Medical cardiac ICU	66	880	5	69,413	0.07	0.00	0.00	0.00	93.9
Cardiothoracic surgical ICU	64	902	4	90,696	0.04	0.00	0.00	0.00	93.8
MICU	84	1,160	20	209,885	0.10	0.00	0.00	0.55	84.5
Medical-surgical ICU									
Major teaching	72	975	21	155,178	0.14	0.00	0.00	0.50	81.9
All others	149	1,928	8	264,805	0.03	0.00	0.00	0.00	95.3
Neurosurgical ICU	25	287	3	33,468	0.09	0.00	0.00	0.00	92.0
PICU	43	602	4	64,413	0.06	0.00	0.00	0.00	95.3
SICU	81	1,163	24	148,455	0.16	0.00	0.00	0.70	84.0
Trauma ICU	24	301	24	61,714	0.39	0.00	0.00	0.54	79.2
ES-Ceph–res *K. pneumoniae*[b]									
Burn ICU	16	208	1	18,683	0.05	NR	NR	NR	NR
Medical cardiac ICU	66	880	4	69,413	0.06	0.00	0.00	0.00	95.5
Cardiothoracic surgical ICU	64	902	5	90,696	0.06	0.00	0.00	0.00	93.8
MICU	84	1,160	18	209,885	0.09	0.00	0.00	0.43	84.5
Medical-surgical ICU									
Major teaching	72	975	16	155,178	0.10	0.00	0.00	0.16	86.1
All others	149	1,928	10	264,805	0.04	0.00	0.00	0.00	96.6
Neurosurgical ICU	25	287	0	33,468	0.00	0.00	0.00	0.00	100.0
PICU	43	602	1	64,413	0.02	0.00	0.00	0.00	97.7
SICU	81	1,163	13	148,455	0.09	0.00	0.00	0.26	87.7
Trauma ICU	24	301	3	61,714	0.05	0.00	0.00	0.44	87.5

NOTE. ES-Ceph–res *K. pneumoniae,* extended-spectrum cephalosporin-resistant *Klebsiella pneumoniae*; Carbp-res *A. baumannii,* carbapenem-resistant *Acinetobacter baumannii*; Carbp-res *P. aeruginosa,* carbapenem-resistant *Pseudomonas aeruginosa*; ICU, intensive care unit; MICU, medical ICU; MRSA, methicillin-resistant *Staphylococcus aureus*; NR, not reported (percentiles are not reported if <20 units of a specific type of PCA reported data); PICU, pediatric ICU; SICU, surgical ICU.

[a] Includes PCAs with >50 device-days reported.

[b] Resistant to ceftriaxone or ceftazidime.

any of these studies, and, similarly, only one study[9] reported any carbapenem-resistant *K. pneumoniae* pathogenic isolates. Our observed resistance percentages for carbapenem-resistant *A. baumannii* were also considerably higher than those from these other studies (33% vs 2%–21% of pathogenic isolates).[9,19,21] The NHSN received reports of this antimicrobial-resistant pathogen from 5%–25% of locations reporting cases of VAP, with higher percentages of reporting among burn and trauma ICUs (Table 10).

The high percentage of resistance to carbapenems observed among *K. pneumoniae* pathogenic isolates was of special concern. Previous laboratory-based surveillance studies evaluating bloodstream infections in hospitalized patients did not identify any pathogenic isolates of carbapenem-resistant *Klebsiella* species among a range of 161–765 pathogenic isolates.[19,26,27] We observed a range of resistance percentages (ie, 4%–11% of pathogenic isolates) among the different types of HAI, with the highest resistance percentages observed for pathogenic isolates associated with CLABSI. The first reports of carbapenem resistance among *Klebsiella* species started to appear from New York hospitals around 2004.[14] The resistance percentage for pathogenic isolates reported from New York hospitals was 21% and contributed to the percentages observed; however, when excluding the hospitals reporting from New York, the resistance percentage remained high (5% of pathogenic isolates), which suggests that this phenotype may be more widespread and more common than previously recognized (ie, the resistance percentage observed is not due solely to healthcare facilities reporting from a single geographic area).

Identification of some of these emerging resistance patterns should alert the infection control community to potential challenges they may face in coming years. However, although each of these described antimicrobial-resistant phenotypes is of concern, the frequency with which each causes HAIs is relatively low, compared with all other pathogens. Among all cases of HAI reported, the following multidrug-resistant pathogens accounted for approximately 16% of infections: MRSA, 8%; vancomycin-resistant *E. faecium,* 4%; carbapenem-resistant *P. aeruginosa,* 2%; extended-spectrum cephalosporin-resistant *K. pneumoniae,* 1%; extended-spectrum cephalosporin-resistant *E. coli,* less than 1%; and carbapenem-resistant *A. baumannii, K. pneumoniae, K. oxytoca,* and *E. coli,* each less than 1%.

A novel metric included in this report is a device-associated infection incidence density rate for selected antimicrobial-resistant pathogens. Data were stratified by type of patient care area, because differences according to hospital location were evident. Further stratification (eg, by the number of beds in the hospital) may be possible as more data become available. The incidence density rate allows for assessment of the variability of antimicrobial resistance among device-associated infections in different patient care areas, and may provide an additional way to assess the efficacy of infection control practices in the future. In general, antimicrobial-resistant device-associated infections due to gram-positive pathogens was more widespread than infections due to gram-negative pathogens. However, overall, less than 50% of units reporting to each of the types of patient care areas reported any device-associated infection due to antimicrobial-resistant pathogens, suggesting that these types of infections are not represented equally among all reporting hospitals. As the NHSN hospitals continue to report cases of HAI during the next several years, the tracking of this distribution of resistant pathogens is needed to assess the utility of this metric.

Direct comparisons of this resistance-percentage data with the data reported in other studies and even with prior NNIS reports may not be informative for several reasons. First, the NHSN includes expansion to non-ICU patient care areas and no minimum bed size criterion for inclusion of a hospital as a member, in contrast to the NNIS system. Second, this NHSN analysis limits reports to device- and procedure-associated HAIs. Third, although the hospitals contributing data to the current report are similar to those that reported to the NNIS system (general, large, acute care hospitals),[28] they include more varied types of hospitals and patient care areas. This report and previous NNIS reports have a limitation in common: the patient population may not be representative of the US patient population as a whole, even though hospitals from 42 states are represented.

Additional limitations of this report include the fact that antimicrobial susceptibility testing was performed by laboratories servicing the hospitals, not by a central laboratory of the Centers for Disease Control and Prevention. Also, a few errors were identified in the data. We looked at the frequency of highly unlikely phenotypes and found a number of reports that noted carbapenem resistance in conjunction with extended-spectrum cephalosporin susceptibility among pathogenic isolates of *K. pneumoniae* and *E. coli.* These unlikely phenotypes were reported in only 0.46% of all *K. pneumoniae* pathogenic isolates, equivalent to 7.5% of the carbapenem-resistant *K. pneumoniae* pathogenic isolates reported, but were reported in 1.13% of all *E. coli* pathogenic isolates, equivalent to 66.7% of the carbapenem-resistant *E. coli* pathogenic isolates reported. These errors may be have been due to incorrect data entry and/or laboratory testing. In response to these findings, and to improve the reliability of the data entered into this system, an edit check will be incorporated, to warn if data on carbapenem resistance in conjunction with extended-spectrum cephalosporin susceptibility are entered. Lastly, accounting for the impact of mandated reporting on this antimicrobial resistance report will be an ongoing challenge. By January 2007, there were 2 states that had required all hospitals to report data to the NHSN, and this number continues to increase. In summary, this first report describes the scope, magnitude, and variability of certain antimicrobial-resistant pathogens associated with device- or procedure-associated HAIs reported to the Patient Safety Component of the NHSN.

ACKNOWLEDGMENTS

We thank the NHSN participants for their ongoing efforts to monitor infections and improve patient safety, and our colleagues in the Division of Healthcare Quality Promotion for their tireless support of this unique public health network.

Financial support. The NHSN surveillance system is supported by the Division of Healthcare Quality Promotion, Centers for Disease Control and Prevention.

Potential conflicts of interest. All authors report no conflicts of interest relevant to this article.

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