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Antimicrobial Use in US Hospitals: Comparison of Results From Emerging Infections Program Prevalence Surveys, 2015 and 2011

Shelley S. Magill,[1] Erin O'Leary,[1,2] Susan M. Ray,[3,4] Marion A. Kainer,[5,a] Christopher Evans,[5] Wendy M. Bamberg,[6,b] Helen Johnston,[6] Sarah J. Janelle,[6] Tolulope Oyewumi,[6,c] Ruth Lynfield,[7] Jean Rainbow,[7] Linn Warnke,[7,d] Joelle Nadle,[8] Deborah L. Thompson,[9,e] Shamima Sharmin,[9,f] Rebecca Pierce,[10] Alexia Y. Zhang,[10] Valerie Ocampo,[10] Meghan Maloney,[11] Samantha Greissman,[11,g] Lucy E. Wilson,[12] Ghinwa Dumyati,[13] and Jonathan R. Edwards[1]; for the Emerging Infections Program Hospital Prevalence Survey Team

[1]Division of Healthcare Quality Promotion, Centers for Disease Control and Prevention, Atlanta, Georgia, USA, [2]Lantana Consulting Group, Thetford, Vermont, USA, [3]Department of Medicine, Emory University, Atlanta, Georgia, USA, [4]Georgia Emerging Infections Program, Decatur, Georgia, USA, [5]Tennessee Department of Health, Nashville, Tennessee, USA, [6]Colorado Department of Public Health and Environment, Denver, Colorado, USA, [7]Minnesota Department of Health, St Paul, Minnesota, USA, [8]California Emerging Infections Program, Oakland, California, USA, [9]New Mexico Department of Health, Santa Fe, New Mexico USA, [10]Oregon Health Authority, Portland, Oregon, USA, [11]Connecticut Emerging Infections Program, Hartford and New Haven, Connecticut, USA, [12]Maryland Department of Health and University of Maryland Baltimore County, Baltimore, Maryland, USA, and [13]New York Emerging Infections Program and University of Rochester Medical Center, Rochester, New York, USA

Background. In the 2011 US hospital prevalence survey of healthcare-associated infections and antimicrobial use 50% of patients received antimicrobial medications on the survey date or day before. More hospitals have since established antimicrobial stewardship programs. We repeated the survey in 2015 to determine antimicrobial use prevalence and describe changes since 2011.

Methods. The Centers for Disease Control and Prevention's Emerging Infections Program sites in 10 states each recruited ≤25 general and women's and children's hospitals. Hospitals selected a survey date from May–September 2015. Medical records for a random patient sample on the survey date were reviewed to collect data on antimicrobial medications administered on the survey date or day before. Percentages of patients on antimicrobial medications were compared; multivariable log-binomial regression modeling was used to evaluate factors associated with antimicrobial use.

Results. Of 12 299 patients in 199 hospitals, 6084 (49.5%; 95% CI, 48.6–50.4%) received antimicrobials. Among 148 hospitals in both surveys, overall antimicrobial use prevalence was similar in 2011 and 2015, although the percentage of neonatal critical care patients on antimicrobials was lower in 2015 (22.8% vs 32.0% [2011]; $P = .006$). Fluoroquinolone use was lower in 2015 (10.1% of patients vs 11.9% [2011]; $P < .001$). Third- or fourth-generation cephalosporin use was higher (12.2% vs 10.7% [2011]; $P = .002$), as was carbapenem use (3.7% vs 2.7% [2011]; $P < .001$).

Conclusions. Overall hospital antimicrobial use prevalence was not different in 2011 and 2015; however, differences observed in selected patient or antimicrobial groups may provide evidence of stewardship impact.

Keywords. anti-infective agents; antimicrobial stewardship; hospitals; epidemiology; prevalence.

Antimicrobial stewardship is necessary to improve patient safety and control antimicrobial resistance [1]. In 2011, the Centers for Disease Control and Prevention (CDC) Emerging Infections Program (EIP) hospital prevalence survey of healthcare-associated infections and antimicrobial use (AU) found that 50% of patients received antimicrobial medications [2]. Other analyses have also shown that AU in US hospitals is widespread [3]. Inappropriate AU in hospitals is common [4] and contributes to the spread of resistant pathogens and *Clostridioides difficile* as well as other adverse events [5].

Recognition of the importance of antimicrobial stewardship has increased [6–9], including US efforts to provide AU tracking tools, stewardship program implementation guidance, and policies establishing stewardship as a national priority. In spring 2012, CDC's National Healthcare Safety Network (NHSN) launched the Antimicrobial Use and Resistance (AUR) Module [10], which provides AU tracking capability for healthcare facilities and uses risk-adjusted Standardized Antimicrobial Administration Ratios to benchmark AU [11]. In March 2014, the CDC recommended that all hospitals have stewardship programs and released the "Core Elements of Hospital

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[a]Present affiliation: Department of Health Policy, Vanderbilt University School of Medicine, Nashville, Tennessee, USA, and Department of Infectious Diseases, Western Health, Melbourne, Victoria, Australia.

[b]Present affiliation: Medical Epidemiology Consulting, Denver, Colorado, USA.

[c]Present affiliation: University of Denver, Denver, Colorado, USA.

[d]Present affiliation: Hennepin County Public Health, Minneapolis, Minnesota, USA.

[e]Present affiliation: Center for Biologics Evaluation and Research, US Food and Drug Administration, Silver Spring, Maryland, USA.

[f]Present affiliation: University of New Mexico Hospital, Albuquerque, New Mexico, USA.

[g]Present affiliation: University of Miami Miller School of Medicine, Miami, Florida, USA.

Correspondence: S. S. Magill, Division of Healthcare Quality Promotion, Centers for Disease Control and Prevention, 1600 Clifton Rd, HB16-3, Atlanta, GA 30333 (smagill@cdc.gov).

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Antibiotic Stewardship" [12], delineating 7 components of effective stewardship programs [12]. The percentage of hospitals with programs meeting all 7 elements increased from 41% in 2014 to 76% in 2017 [13, 14]. In September 2014, the White House issued an Executive Order and the "National Strategy for Combating Antibiotic-Resistant Bacteria," establishing antimicrobial resistance as a national security priority and mandating federal actions to improve AU [15, 16]. Following the "National Strategy" release, efforts to drive improvements in AU nationally have continued; examples include the "National Action Plan for Combating Antibiotic-Resistant Bacteria," released by the White House in March 2015 [17], and a Centers for Medicare and Medicaid Services condition of participation requiring hospitals to have stewardship programs, finalized in September 2019 [18].

We repeated the hospital survey in 2015 with objectives that included updating AU prevalence estimates and describing inpatient AU changes since 2011.

METHODS

Hospitals and Patients

The survey was conducted in 10 EIP sites (California, Colorado, Connecticut, Georgia, Maryland, Minnesota, New Mexico, New York, Oregon, Tennessee). The human subjects advisor in the CDC's National Center for Emerging and Zoonotic Infectious Diseases determined the survey was a nonresearch public health activity. The EIP sites and hospitals determined the survey was a nonresearch activity or approved the survey with informed-consent waiver. Survey methods have been described [2, 19, 20]. The EIP sites contacted hospitals that participated in the 2011 survey, then recruited additional general, women's and children's hospitals, up to 25 hospitals per site, using a stratified random-sampling approach based on acute-care–staffed bed size. Each hospital selected a survey date between May and September 2015. Patients were randomly selected from the hospital's morning census on the survey date as described previously [20].

Data Collection

Hospital staff completed a questionnaire on hospital characteristics, infection control, and antimicrobial stewardship. Hospital or EIP staff reviewed medical records to collect patients' initial demographic and clinical data, including AU screening criteria (receiving or scheduled to receive antimicrobial medications on the survey date or day before the survey). This initial data collection occurred on the survey date or retrospectively. This was a change from 2011, in which most initial data collection occurred on the survey date. EIP staff conducted retrospective medical record reviews for patients meeting the AU screening criteria and for patients for whom AU was unknown at the time of the survey to collect antimicrobial medication names, routes, dates, rationales for use, infection-treatment sites and onset locations, and surgical prophylaxis duration and procedures. Antibacterial, antifungal, and selected antimycobacterial and antiviral medications administered via intravenous (IV), intramuscular (IM), oral/enteral, or inhaled routes were included (Supplementary Table 1).

Analysis

The EIP staff entered data into a secure online system. The CDC staff evaluated data for quality and consistency; EIP staff re-reviewed medical records as needed to address discrepancies and correct errors. Data downloaded on 16 November 2017 were analyzed using SAS version 9.4 (SAS Institute Inc, Cary, NC) or OpenEpi version 3.01 [21]. Antimicrobial medications were classified using fourth-level (chemical subgroup) and fifth-level (individual chemical substance) codes of the World Health Organization Anatomical Therapeutic Chemical (WHO ATC) classification system [22, 23] (Supplementary Table 1). Antimicrobial medications given on the survey date and/or the day before were considered unique based on the patient and fifth-level code [2]. For example, IV levofloxacin given on the day before the survey and oral levofloxacin given on the survey date to a single patient were considered 1 antimicrobial medication. Oral and IV vancomycin given to a single patient on the survey date or the day before were considered 2 medications.

Antimicrobial use prevalence was defined as the percentage of patients receiving 1 or more antimicrobial medication on the survey date or day before. We compared patient characteristics and AU prevalence using mid-*P* exact or chi-square tests for categorical variables and median tests for continuous variables. We used the same AU screening criteria in both the 2011 and 2015 surveys, except that in 2011 we employed a screening criteria modification for dialysis patients that included receipt of parenteral vancomycin or aminoglycosides in the 4 days before the survey. In 2015, we did not use this modification. Therefore, we excluded 2011 patients who met only the dialysis modification (but did not receive antimicrobial medications on the survey date or day before) from analyses comparing 2011 and 2015 data. We used multivariable log-binomial regression modeling with forward selection of variables to identify patient and hospital factors associated with AU in the 2015 survey. Model fit was evaluated using Akaike and Bayesian information criteria and Wald and likelihood ratio chi-square tests. We evaluated multiple parameterizations of selected variables; variable levels with similar estimates of risk were further grouped so that final parameterizations were the most parsimonious.

RESULTS

Hospitals

A total of 199 hospitals participated in the 2015 survey: 96 (48.2%) were categorized as small hospitals (<150

acute-care–staffed beds), 76 (38.2%) as medium (150–399 beds), and 27 (13.6%) as large (≥400 beds). Selected characteristics of participating hospitals were reported previously [20]; others are shown in Supplementary Table 2. Most hospitals (158, 79.4%) reported having an antimicrobial stewardship team. The median number of patients included in the survey per hospital was 75 (interquartile range, 40–75), and 197 hospitals (99.0%) had 1 or more patient on antimicrobial medications.

Prevalence of Antimicrobial Use

Of 12 299 patients, 6084 (49.5%; 95% confidence interval [CI], 48.6–50.4%) received antimicrobial medications on the survey date or day before: 5210 patients on the survey date (42.4%; 95% CI, 41.5–43.2%) and 5494 on the day before (44.7%; 95% CI, 43.8–45.6%). Patient characteristics are reported in Supplementary Table 3. Among locations with 50 or more patients surveyed (28/64 total location types, 43.8%), AU prevalence was highest in surgical critical care (55/75, 73.3%) and lowest in newborn nurseries (11/373, 2.9%) (Supplementary Table 4).

Of 148 hospitals in both the 2011 and 2015 surveys, 147 had 1 or more patients on antimicrobial medications. In these 148 hospitals in 2011, after excluding patients who met only the dialysis modification, 4606 of 9283 patients (49.6%; 95% CI, 48.6–50.6%) received 8110 antimicrobial medications; in 2015, 4590 of 9169 patients (50.1%; 95% CI, 49.0–51.1%) received 8091 antimicrobial medications ($P = .55$).

For most hospital locations, there were no differences in AU prevalence in the 2 surveys (Table 1). Antimicrobial use prevalence in neonatal critical care locations, however, was 22.8% in 2015 and 32.0% in 2011 ($P = .006$).

Factors Associated With Antimicrobial Use

In 2015, multiple patient and hospital characteristics were independent AU risk factors in the final model, including patient groups based on hospital location and age, presence of selected

Table 1. Percentages of Patients on Antimicrobials in Adult, Pediatric, and Neonatal Critical Care and Non–Critical Care Inpatient Locations Combined and in Individual Inpatient Location Types With ≥50 Patients Surveyed, 2011 Versus 2015, Among 148 Hospitals Participating in Both Surveys

	2011 Survey		2015 Survey		
Inpatient Location[a]	Total No. of Patients	No. of Patients on Antimicrobial Medications (%)	Total No. of Patients	No. of Patients on Antimicrobial Medications (%)	*P*[b]
Adult critical care, all	955	610 (63.9)	921	573 (62.2)	.46
Medical/surgical critical care unit	476	315 (66.2)	550	342 (62.2)	
Medical critical care unit	201	131 (65.2)	153	105 (68.6)	
Surgical critical care unit	73	57 (78.1)	63	46 (73.0)	
Adult non–critical care, all	6294	3382 (53.7)	6143	3406 (55.5)	.06
Medical/surgical ward	2118	1191 (56.2)	2275	1322 (58.1)	
Medical ward	1342	760 (56.6)	1192	632 (53.0)	
Surgical ward	774	418 (54.0)	784	456 (58.2)	
Telemetry ward	647	272 (42.0)	558	241 (43.2)	
Stepdown unit	355	182 (51.3)	348	177 (50.9)	
Orthopedic ward	338	197 (58.3)	289	192 (66.4)	
Hematology/oncology unit	306	174 (56.9)	235	159 (67.7)	
Mixed acuity adult unit	59	32 (54.2)	132	59 (44.7)	
Neurology ward	71	21 (29.6)	78	34 (43.6)	
Pediatric critical care, all	96	66 (68.8)	109	70 (64.2)	.50
Medical/surgical pediatric critical care unit	57	40 (70.2)	75	49 (65.3)	
Pediatric non–critical care, all	469	244 (52.0)	470	241 (51.3)	.82
Medical/surgical pediatric ward	227	120 (52.9)	221	110 (49.8)	
Medical pediatric ward	88	44 (50.0)	108	51 (47.2)	
Neonatal critical care, all	337	108 (32.0)	372	85 (22.8)	.006
Neonatal critical care unit level III	204	66 (32.4)	242	62 (25.6)	
Neonatal critical care unit level II/III	133	42 (31.6)	130	23 (17.7)	
Neonatal non–critical care, all	396	24 (6.1)	344	21 (6.1)	.98
Nursery ward	332	9 (2.7)	273	8 (2.9)	
Special care nursery	64	15 (23.4)	71	13 (18.3)	
Mother–baby units, all	728	167 (22.9)	798	188 (23.6)	.78
Labor/delivery/recovery/postpartum ward	319	63 (19.7)	287	74 (25.8)	
Postpartum ward	306	72 (23.5)	391	77 (19.7)	
Labor and delivery ward	103	32 (31.1)	120	37 (30.8)	

Mixed acuity and stepdown adult and pediatric units are included in adult non–critical care and pediatric non–critical care, respectively.

[a]Excludes 20 patients (8 in the 2011 survey and 12 in the 2015 survey) in mixed-age locations.

[b]Mid-*P* exact test.

devices, primary payer, race, length of stay, annual hospital discharges, and region (Supplementary Table 5). After adjusting for other factors, AU risk was highest for patients in adult or pediatric critical care units, oncology wards, or other specialty care areas (adjusted relative risk [RR], 20.30; 95% CI, 12.17–37.79, $P < .001$) and selected adult wards (medical-surgical, surgical, gerontology, genitourinary, orthopedic, and pulmonary) (adjusted RR, 21.97; 95% CI, 13.18–40.87; $P < .001$).

Common Antimicrobials

Of 10 612 antimicrobial medications in the 2015 survey, the most common were parenteral vancomycin (1258, 11.9%), cefazolin (1117, 10.5%), ceftriaxone (1010, 9.5%), piperacillin-tazobactam (827, 7.8%), and levofloxacin (798, 7.5%) (Supplementary Table 6). The most common groups were third- or fourth-generation cephalosporins (1531, 14.4%), glycopeptides (1258, 11.9%), fluoroquinolones (1241, 11.7%), first-generation cephalosporins (1206, 11.4%), and penicillin combinations, including β-lactamase inhibitors (1093, 10.3%) (Supplementary Table 6).

These were also the most common groups in 2011 and 2015 among hospitals that participated in both surveys, although rank order differed (Table 2). In these hospitals, the percentage of patients receiving fluoroquinolones was lower in 2015 (2015 vs 2011: 10.1% vs 11.9%; $P < .001$). In contrast, the percentage of patients receiving first-generation cephalosporins was higher in 2015 (2015 vs 2011: 9.8% vs 8.5%; $P = .003$), as was the percentage of patients receiving third- or fourth-generation cephalosporins (2015 vs 2011: 12.2% vs 10.7%; $P = .002$) or carbapenems (2015 vs 2011: 3.7% vs 2.7%; $P < .001$). Antimicrobial use in different age groups and inpatient locations in the 2011 and 2015 surveys is shown in Supplementary Tables 7 and 8.

Rationale for Antimicrobial Use

Among 6084 patients on antimicrobial medications in the 2015 survey, the most common rationale was infection treatment (4476 patients [73.6%] receiving 8138 antimicrobial medications). Other rationales were surgical prophylaxis (1185 patients [19.5%], 1334 antimicrobial medications), medical prophylaxis (584 patients [9.6%], 860 antimicrobial medications), non–infection-related reasons (77 patients [1.3%], 78 antimicrobial medications), and no documented rationale (229 patients [3.8%], 265 antimicrobial medications) (Table 3, Supplementary Table 9). The rationale distributions for antimicrobial medications in the 2011 and 2015 surveys among hospitals participating in both surveys are shown in Supplementary Table 10. In 2011 and 2015, the percentage of medications with no documented rationale was low (2011 vs 2015: 4.6% vs 2.4%).

Infection Treatment

Most patients received antimicrobial medications for infections reported to be community-onset only (3433/4476 patients [76.7%], 6052 antimicrobials) (Supplementary Table 11). Four of the 5 most common antimicrobial medications used to treat community-onset infections were also among the most common medications for survey hospital- or long-term care facility–onset infections, although the rank order differed: ceftriaxone, parenteral vancomycin, levofloxacin, and piperacillin-tazobactam (Table 4). Pneumonia was the most common reason for antimicrobial treatment, accounting for 2311 of 8138 (28.4%) treatment antimicrobial medications (Supplementary Table 12). More than two-thirds of patients who received antimicrobial treatment (3077/4476, 68.7%) were treated for pneumonia, other lower respiratory infection, urinary tract infection, or skin and soft tissue infection.

We identified differences in the percentages of patients receiving treatment for selected infections in 2011 and 2015 in hospitals that participated in both surveys (Table 5). A larger percentage of patients in the 2015 survey were receiving antimicrobial medications for infections of undetermined site, which included empiric sepsis treatment (2015 vs 2011: 11.5% vs 9.0%; $P < .001$). In contrast, fewer patients in 2015 were receiving gastrointestinal tract infection treatment (2015 vs 2011: 10.9% vs 13.0%; $P = .006$).

Surgical Prophylaxis

More than half of antimicrobial medications for surgical prophylaxis were given for 5 procedures: "other" procedures (201/1334, 15.1%), knee replacements (165, 12.4%), hip replacements (132, 9.9%), cesarean sections (125, 9.4%), and open reductions of fractures (103, 7.7%). Of 1334 antimicrobial medications for surgical prophylaxis, 1285 (96.3%) were given only for surgical prophylaxis (ie, without other reported rationales, such as infection treatment) to 1151 patients with 1153 surgical procedures. Prophylaxis duration was 24 hours or less for 969 of 1285 antimicrobial medications (75.4%), more than 24 hours for 260 medications (20.2%), and unknown for 56 medications (4.4%). Overall, 238 patients (20.7% of patients receiving antimicrobial medications given for surgical prophylaxis only) received prophylaxis for more than 24 hours (Supplementary Table 13).

DISCUSSION

Approximately half of patients in the 2015 survey received antimicrobial medications on the survey date or day before, unchanged from 2011. Although overall AU prevalence was no different, we observed some potentially promising changes in 2015, such as lower prevalence in neonatal critical care locations and a smaller percentage of patients on fluoroquinolones. Findings of potential concern include a higher prevalence of extended-spectrum cephalosporins and carbapenem use, the percentage of patients receiving

Table 2. Percentages of Patients on Selected Antimicrobial Medications, 2011 Versus 2015, Among 148 Hospitals Participating in Both Surveys

Antimicrobial Group	No. of Patients (%)		P^a
	2011 Survey (N = 9283)	2015 Survey (N = 9169)	
Fluoroquinolones	1104 (11.9)	930 (10.1)	<.001
Levofloxacin	573	602	
Ciprofloxacin	395	304	
Moxifloxacin	150	33	
Third-or fourth-generation cephalosporins	994 (10.7)	1115 (12.2)	.002
Ceftriaxone	697	733	
Cefepime	173	305	
Cefotaxime	64	28	
Ceftazidime	56	46	
Cefpodoxime	15	13	
Cefdinir	5	11	
Ceftizoxime	3	0	
Cefixime	1	4	
Ceftazidime-avibactam	Not available	1	
Glycopeptides	987 (10.6)	951 (10.4)	.56
Vancomycin (parenteral)	987	951	
Telavancin	1	0	
Penicillin combinations, including β-lactamase inhibitors	845 (9.1)	796 (8.7)	.32
Piperacillin-tazobactam	674	628	
Ampicillin-sulbactam	134	117	
Amoxicillin-clavulanate	61	81	
Ticarcillin-clavulanate	4	0	
First-generation cephalosporins	791 (8.5)	897 (9.8)	.003
Cefazolin	744	850	
Cephalexin	58	59	
Cefadroxil	2	1	
Macrolides	388 (4.2)	340 (3.7)	.10
Azithromycin	351	303	
Clarithromycin	13	4	
Erythromycin	25	34	
Imidazole derivatives	346 (3.7)	378 (4.1)	.17
Metronidazole (parenteral)	346	378	
Triazole derivatives	301 (3.2)	293 (3.2)	.86
Fluconazole	246	236	
Voriconazole	48	35	
Posaconazole	7	16	
Itraconazole	3	6	
Isavuconazole	Not available	2	
Carbapenems	247 (2.7)	337 (3.7)	<.001
Meropenem	86	232	
Ertapenem	74	87	
Imipenem	49	25	
Doripenem	40	0	
Intestinal antibiotics	238 (2.6)	238 (2.6)	.89
Vancomycin (oral)	111	108	
Nystatin	96	70	
Rifaximin	35	64	
Neomycin	2	3	
Fidaxomicin	…	2	
Other antibacterials	144 (1.6)	94 (1.0)	.002
Linezolid	93	67	
Daptomycin	55	26	
Methenamine	Not included	1	
Tetracyclines	105 (1.1)	142 (1.5)	.01
Doxycycline	71	125	
Tigecycline	22	6	
Minocycline	10	10	
Tetracycline	3	1	

The numbers of patients on specific antimicrobial medications may sum to more than the total number of patients receiving a particular antimicrobial medication group since patients could have received more than 1 medication in a given group.

[a]$\chi 2$ test.

Table 3. Ten Most Common Antimicrobial Medications Administered to Hospital Patients, by Rationale: 2015 Survey

Antimicrobial Medications (n, %)			
For All Rationales (N = 10 612)	For Treatment of Active Infection (N = 8138)	For Surgical Prophylaxis (N = 1334)	For Medical Prophylaxis (N = 860)
Vancomycin, parenteral (1258, 11.9)	Vancomycin, parenteral (1134, 13.9)	Cefazolin (872, 65.4)	Acyclovir (120, 14.0)
Cefazolin (1117, 10.5)	Ceftriaxone (966, 11.9)	Vancomycin, parenteral (98, 7.4)	Trimethoprim-sulfamethoxazole (84, 9.8)
Ceftriaxone (1010, 9.5)	Piperacillin-tazobactam (786, 9.7)	Clindamycin (72, 5.4)	Fluconazole (78, 9.1)
Piperacillin-tazobactam (827, 7.8)	Levofloxacin (721, 8.9)	Metronidazole, parenteral (48, 3.6)	Cephalexin (52, 6.1)
Levofloxacin (798, 7.5)	Metronidazole, parenteral (434, 5.3)	Cefoxitin (37, 2.8)	Ampicillin (50, 5.8)
Metronidazole, parenteral (501, 4.7)	Cefepime (368, 4.5)	Piperacillin-tazobactam (27, 2.0)	Levofloxacin (49, 5.7)
Ciprofloxacin (397, 3.7)	Azithromycin (354, 4.4)	Gentamicin (26, 2.0)	Benzylpenicillin (47, 5.5)
Azithromycin (391, 3.7)	Ciprofloxacin (338, 4.2)	Ciprofloxacin (22, 1.7)	Valacyclovir (31, 3.6)
Cefepime (380, 3.6)	Meropenem (294, 3.6)	Cefotetan (21, 1.6)	Azithromycin (25, 2.9)
Meropenem (306, 2.9)	Fluconazole (197, 2.4)	Ertapenem (20, 1.5)	Vancomycin, parenteral (24, 2.8)

prolonged surgical prophylaxis, and the observation that broad-spectrum AU, including for community-onset infections, remained common in 2015.

Point-prevalence surveys of AU in other countries provide context for our results. Data from the European Centre for Disease Prevention and Control (ECDC) have shown that AU in European hospitals is less prevalent than in the United States. In a 2016–2017 survey, AU point prevalence was 32.9% (weighted prevalence, 30.5%; range, 15.9–55.6%) [24] compared to 42.4% in our survey on the survey date. In selected countries in the ECDC survey, particularly in Eastern and Southern Europe, the observed prevalence was similar to or higher than the AU point prevalence in our survey—for example, 42.2% in Romania and 55.6% in Greece [24]. In the 2015 Global Point Prevalence Survey (Global-PPS), conducted in 53 countries, hospital AU point prevalence varied widely across regions, from 27.4% to 50%; among 24 North American hospitals, AU point prevalence was 38.6% (country range, 30.9–44.8%) [25], similar to the point prevalence we observed on the survey date.

Despite differences in AU prevalence among countries, some common themes have emerged. Pneumonia or respiratory infection was the most common reason for hospital AU in our survey as well as the ECDC survey and Global-PPS, accounting for approximately one-third of all antimicrobial treatment in the ECDC survey and in our survey, and 19% of patients receiving antimicrobial medications in the Global-PPS. Also, prolonged surgical prophylaxis was common in each of the surveys (54.2% in the ECDC survey, 52.4% in the Global-PPS, and 20.7% in our survey) [24, 25]. These findings suggest opportunities for multinational collaborations to improve hospital AU.

Prevalence surveys provide valuable information on AU globally, and in some cases may facilitate comparisons among countries, although data on changes in hospital AU over time in individual countries or regions are limited. An analysis of US hospital prescribing data from 2006 to 2012 showed that 55.1% of patients received at least 1 antibiotic dose during their hospitalization [3]. Over this period, overall AU did not change, although the authors reported increases in days of therapy per 1000 patient-days for selected antimicrobial medications, including third- or fourth-generation cephalosporins and carbapenems, and decreases in others, including fluoroquinolones [3]. The authors hypothesized that decreases in fluoroquinolone use may have been part of *C. difficile* prevention efforts and in response to increasing resistance among certain gram-negative bacteria.

Table 4. Ten Most Common Antimicrobial Medications Given to Treat Infections by Onset Location, Among 8138 Antimicrobial Medications Given to Treat Infection in Patients in the 2015 Survey

Antimicrobial Medications (n, %)		
For Community-Onset Infections (N = 6052)	For Survey Hospital-Onset Infections (N = 1325)	For Long-term Care Facility–Onset Infections (N = 628)
Ceftriaxone (819, 13.5)	Vancomycin, parenteral (182, 13.7)	Vancomycin, parenteral (114, 18.2)
Vancomycin, parenteral (819, 13.5)	Piperacillin-tazobactam (113, 8.5)	Piperacillin-tazobactam (64, 10.2)
Levofloxacin (596, 9.8)	Cefepime (87, 6.6)	Ceftriaxone (56, 8.9)
Piperacillin-tazobactam (595, 9.8)	Ceftriaxone (80, 6.0)	Cefepime (54, 8.6)
Metronidazole, parenteral (341, 5.6)	Levofloxacin (77, 5.8)	Levofloxacin (46, 7.3)
Azithromycin (316, 5.2)	Fluconazole (65, 4.9)	Meropenem (33, 5.3)
Ciprofloxacin (261, 4.3)	Meropenem (64, 4.8)	Metronidazole, parenteral (27, 4.3)
Cefepime (229, 3.8)	Metronidazole, parenteral (60, 4.5)	Azithromycin (21, 3.3)
Meropenem (195, 3.2)	Ciprofloxacin (53, 4.0)	Fluconazole (21, 3.3)
Clindamycin (153, 2.5)	Gentamicin (52, 3.9)	Vancomycin, oral (16, 2.6)

Antimicrobial medications given to treat infections with multiple onset locations reported were excluded.

Table 5. Percentages of Patients Receiving Antimicrobial Medications to Treat Infections, by Therapeutic Site, Among 148 Hospitals That Participated in Both the 2011 and 2015 Surveys

	Hospitals Participating in Both Surveys			All 2015 Hospitals
Therapeutic Site	No. of Patients, 2011 Survey (%) (N = 3478)	No. of Patients, 2015 Survey (%) (N = 3372)	*P*[a]	No. of Patients (%) (N = 4476)
Lower respiratory	1166 (33.5)	1145 (34.0)	.71	1526 (34.1)
Pneumonia	…[b]	921 (27.3)		1232 (27.5)
Other lower respiratory	…[b]	252 (7.5)		328 (7.3)
Urinary tract	768 (22.1)	755 (22.4)	.76[c]	1021 (22.8)
Skin and soft tissue	549 (15.8)	579 (17.2)	.12[c]	804 (18.0)
Undetermined/empirical	313 (9.0)	388 (11.5)	<.001	481 (10.7)
Bloodstream	327 (9.4)	291 (8.6)	.27	386 (8.6)
Gastrointestinal	452 (13.0)	366 (10.9)	.006	495 (11.1)
Clostridioides difficile infection	…[b]	153 (4.5)		201 (4.5)
Other gastrointestinal	…[b]	223 (6.6)		307 (6.9)
Intraabdominal	156 (4.5)	186 (5.5)	.05	229 (5.1)
Bone and joint	158 (4.5)	138 (4.1)	.36	183 (4.1)
Hepatobiliary	87 (2.5)	104 (3.1)	.14	148 (3.3)
Ear, eye, nose, mouth, throat	149 (4.3)	143 (4.2)	.93	177 (4.0)
Central nervous system	64 (1.8)	61 (1.8)	.92	79 (1.8)
Reproductive	40 (1.2)	49 (1.5)	.27	69 (1.5)
Cardiovascular	47 (1.4)	31 (0.9)	.09	41 (0.9)
Disseminated	31 (0.9)	24 (0.7)	.41	29 (0.6)
Unknown	15 (0.4)	18 (0.5)	.55	27 (0.6)
Other	3 (0.09)	Not collected	…	Not collected

Numbers in columns may sum to more than 100% because patients could receive antimicrobial medications for multiple therapeutic sites.

[a]Mid-*P* exact test unless otherwise indicated.

[b]Lower respiratory and gastrointestinal infections were not subdivided into pneumonia vs other lower respiratory infections or *C. difficile* vs other gastrointestinal infections in the 2011 survey.

[c]$\chi 2$ test.

The authors suggested this latter factor was a possible explanation for increases in extended-spectrum cephalosporin and carbapenem use [3].

These factors may also explain differences we observed from 2011 to 2015. The incidence of infections due to extended-spectrum β-lactamase–producing Enterobacteriaceae is increasing [26, 27], which could explain the higher prevalence of carbapenem use we observed in 2015. Data supporting the association between fluoroquinolones and *C. difficile* infection continue to accumulate. Dingle and colleagues [28] reported that a major reason for the declining incidence of *C. difficile* infection in England was restriction of fluoroquinolone use leading to a decrease in the prevalence of fluoroquinolone-resistant *C. difficile* strains such as NAP1/027. Studies from the United States also report lower *C. difficile* rates in association with reduced fluoroquinolone prescribing [29–31]. Moreover, prudent fluoroquinolone use is necessary due to warnings issued by the US Food and Drug Administration regarding serious adverse events [32]. To achieve further reductions, guidelines are needed to assist prescribers in selecting fluoroquinolone alternatives [33].

While there was no reduction in overall AU prevalence from 2011 to 2015, there was a notable reduction among neonates in critical care locations. The percentage of neonatal critical care patients on antimicrobial medications was approximately 30% lower in 2015 than in 2011. Although we are not able to tie this difference to specific interventions, intensive stewardship efforts within the neonatal provider community may have contributed [34–37]. In addition to growing awareness of microbiome alterations [38] and other adverse consequences of AU in neonates [39–41], a nationally available neonatal "sepsis calculator" utilizing a multivariate risk assessment to guide early-onset sepsis treatment was implemented [42–44]; its use appears to reduce antimicrobial prescribing without negatively affecting outcomes [45]. Empiric AU is often necessary during the initial treatment of an ill patient, which presents a challenge to the goal of reducing AU to the minimum level that is necessary and safe. However, more and better tools like the neonatal sepsis calculator and rapid diagnostics, once validated and in wider use, would facilitate targeted, higher-quality prescribing.

Our analysis showed that, although multiple hospital and patient characteristics were associated with AU, combinations of patient age and inpatient location were most important. Targeted approaches that direct resources toward improving selection or duration of antimicrobial treatment on specific inpatient units or for specific conditions may be more effective than broad-based strategies. Our data suggest that areas of opportunity for evaluating antimicrobial prescribing quality in hospitals may include AU in selected adult non–critical care units,

prolonged surgical prophylaxis, and treatment for infection types that drive most hospital AU: pneumonia and other lower respiratory, skin and soft tissue, and urinary tract infections.

Our survey has limitations, as described previously [2]. Minor data collection modifications in 2015 could have affected AU prevalence; however, we were able to address these in the analysis. We were only able to evaluate AU at 2 time points; additional data are needed to determine whether changes from 2011 to 2015 have persisted. Some of the observed changes in AU were small and of uncertain clinical significance. Finally, these data do not address antimicrobial prescribing quality. Survey staff gathered additional information for selected clinical scenarios to describe prescribing quality; analysis is ongoing.

Prevalence surveys remain a valuable complement to other large-scale assessments of US inpatient AU, including those using electronic health record datasets or antimicrobial consumption data from the NHSN AUR Module. These surveys, including a similar survey conducted in nursing homes in 2017 [46], provide opportunities to assess not only the prevalence of AU in healthcare facilities but also the reasons for and quality of use at the patient level.

Supplementary Data

Supplementary materials are available at *Clinical Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Notes

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