Prevalence of Antimicrobial Use in US Acute Care Hospitals, May-September 2011

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IMPORTANCE Inappropriate antimicrobial drug use is associated with adverse events in hospitalized patients and contributes to the emergence and spread of resistant pathogens. Targeting effective interventions to improve antimicrobial use in the acute care setting requires understanding hospital prescribing practices.

OBJECTIVE To determine the prevalence of and describe the rationale for antimicrobial use in participating hospitals.

DESIGN, SETTING, AND PARTICIPANTS One-day prevalence surveys were conducted in acute care hospitals in 10 states between May and September 2011. Patients were randomly selected from each hospital’s morning census on the survey date. Data collectors reviewed medical records retrospectively to gather data on antimicrobial drugs administered to patients on the survey date and the day prior to the survey date, including reasons for administration, infection sites treated, and whether treated infections began in community or health care settings.

MAIN OUTCOMES AND MEASURES Antimicrobial use prevalence, defined as the number of patients receiving antimicrobial drugs at the time of the survey divided by the total number of surveyed patients.

RESULTS Of 11,282 patients in 183 hospitals, 5635 (49.9%; 95% CI, 49.0%-50.9%) were administered at least 1 antimicrobial drug; 77.5% (95% CI, 76.6%-78.3%) of antimicrobial drugs were used to treat infections, most commonly involving the lower respiratory tract, urinary tract, or skin and soft tissues, whereas 12.2% (95% CI, 11.5%-12.8%) were given for surgical and 5.9% (95% CI, 5.5%-6.4%) for medical prophylaxis. Of 7641 drugs to treat infections, the most common were parenteral vancomycin (1103, 14.4%; 95% CI, 13.7%-15.2%), ceftriaxone (825, 10.8%; 95% CI, 10.1%-11.5%), piperacillin-tazobactam (788, 10.3%; 95% CI, 9.6%-11.0%), and levofloxacin (694, 9.1%; 95% CI, 8.5%-9.7%). Most drugs administered to treat infections were given for community-onset infections (69.0%; 95% CI, 68.0%-70.1%) and to patients outside critical care units (81.6%; 95% CI, 80.4%-82.7%). The 4 most common treatment antimicrobial drugs overall were also the most common drugs used for both community-onset and health care facility-onset infections and for infections in patients in critical care and noncritical care locations.

CONCLUSIONS AND RELEVANCE In this cross-sectional evaluation of antimicrobial use in US hospitals, use of broad-spectrum antimicrobial drugs such as piperacillin-tazobactam and drugs such as vancomycin for resistant pathogens was common, including for treatment of community-onset infections and among patients outside critical care units. Further work is needed to understand the settings and indications for which reducing antimicrobial use can be most effectively and safely accomplished.
Antimicrobial drugs have saved countless lives over the past century, and studies show that timely administration of appropriate antimicrobial therapy to severely ill, infected patients is essential to avoid infection-related morbidity and mortality.\(^1\)\(^-\)\(^3\) Despite the evidence supporting early, appropriate therapy, a substantial proportion of antimicrobial use in US acute care hospitals may be inappropriate, based on factors such as lack of indication or incorrect drug selection, dosing levels, or treatment duration.\(^4\)\(^-\)\(^6\) Exposure to antimicrobial drugs is also a risk factor for the acquisition of resistant and difficult-to-treat pathogens, such as carbapenem-resistant Enterobacteriaceae\(^7\)\(^-\)\(^8\) and *Clostridium difficile*,\(^9\)\(^-\)\(^10\) and antimicrobial drugs are leading causes of adverse drug events.\(^11\)\(^-\)\(^12\) Inappropriate antimicrobial use needlessly puts patients at risk of these complications.

One aspect of a multifaceted approach to reducing antimicrobial-resistant infections is improving antimicrobial use.\(^13\)\(^-\)\(^14\) To improve use and reduce preventable harm in US hospitals, it is necessary to understand inpatient antimicrobial-drug-use epidemiology. There have been few large-scale efforts to define antimicrobial-drug-use epidemiology in US acute care hospitals.\(^15\)\(^-\)\(^17\) Studies performed in the last decade have shown that approximately 60% of adult and pediatric inpatients receive antimicrobial drugs during their hospitalizations.\(^15\)\(^-\)\(^16\) Significant increases in the use of piperacillin-tazobactam, carbapenems, and vancomycin in adult patients were seen in an analysis of 2002–2006 data.\(^15\) Most studies to date have used administrative data and focused on measuring the volume of antimicrobial use, without assessing the rationale for use at the patient level. We performed a multistate, acute care hospital antimicrobial-drug-use prevalence survey in 2011 to determine the prevalence of inpatient antimicrobial-drug use, the most common antimicrobial drug types, and the reasons for their use.

### Methods

#### Hospital and Patient Selection

The antimicrobial-drug use survey was performed in conjunction with a survey of health care–associated infections conducted by the Centers for Disease Control and Prevention (CDC) and the Emerging Infections Program (EIP) in California, Colorado, Connecticut, Georgia, Maryland, Minnesota, New Mexico, New York, Oregon, and Tennessee.\(^18\) The CDC deemed the survey to be a public health surveillance activity, and participating state health departments, EIP academic partners, and hospitals either approved the project in accordance with human subjects research requirements with waivers of informed consent or determined the survey was not human subjects research.

Within each EIP site’s catchment area, general acute care and children’s hospitals were stratified according to bed size. Random samples were drawn from each stratum, with a goal of engaging up to 13 small (<150 beds), 9 medium (150–399 beds), and 3 large (≥400 beds) hospitals per site. These goal numbers were based on the size distribution of all general acute care hospitals in the EIP sites, the numbers of hospitals within the selected catchment areas for the survey, and taking into account EIP site resources needed to support the survey. An alternate hospital from within the same bed-size stratum was recruited in cases for which a selected hospital declined to participate.

Each hospital performed a 1-day survey that included a random sample of acute care inpatients identified from the morning census on the survey date. Large hospitals surveyed 100 patients, and small and medium hospitals surveyed either 75 patients or all eligible acute care inpatients if the census was fewer than 75 patients on the survey date. The target numbers of patients per hospital were selected to enhance the efficiency of survey planning and minimize burden to hospitals while ensuring adequate precision of health care–associated infection prevalence estimates.

#### Data Collection

Data collectors reviewed medical records on the survey date to determine whether patients may have been receiving enteral (excluding rectal), intravenous, intramuscular, or inhaled antimicrobial drugs (Methods 1 in the Supplement) at the time of the survey, using the following screening criteria: (1) the patient was administered or was scheduled to be administered at least 1 antimicrobial drug on the survey date or the calendar day prior to the survey date; (2) the patient was a patient undergoing dialysis who received or was scheduled to receive parenteral vancomycin or an aminoglycoside during the 4 days prior to the survey date; or (3) the patient’s antimicrobial drug information was unknown or was not available at the time of the survey. Topical antimicrobials were excluded. The EIP surveillance epidemiologists retrospectively reviewed medical records of patients who met screening criteria to collect information on antimicrobial drugs given to the patient on the survey date or the calendar day prior to the survey date and parenteral vancomycin and aminoglycosides when administered during the 4 calendar days prior to the survey date to patients undergoing dialysis. Acceptable sources of antimicrobial drug administration data included electronic or paper emergency department and inpatient medication administration records and operating room flow sheets.

At the time of data collection, antimicrobial drugs were considered unique at the drug-administration route level: each antimicrobial drug could be recorded up to 2 times for a given patient if that antimicrobial drug was administered via 2 different routes at the time of the survey (eg, intravenous to oral administration transition for certain antimicrobial drugs). For each drug-route combination, data collectors recorded the rationale for use: treatment of infection, surgical prophylaxis, medical prophylaxis, a noninfection-related reason, or unknown rationale. Empirical use of antimicrobial drugs for suspected infection was considered treatment. Noninfection-related reasons for antimicrobial drug administration included treatment of conditions not primarily considered to be infectious in nature, such as erythromycin for impaired gastrointestinal motility. For antimicrobial drugs given to treat infections, data collectors identified the anatomical site of infection and the location of onset (survey hospital, other health care facility, or community) based on clinician documentation in the medical record. Although National Healthcare Safety Network (NHSN) health care–associated infection surveillance definitions were used in the health care–associated infection portion of the
survey, they were not used in collecting data on infections for which antimicrobial drugs were given. Multiple rationales, infection sites, and onset locations could be reported for each drug.

**Analysis**

Data analysis was performed using SAS version 9.3 (SAS Institute Inc) and OpenEpi version 3.0.1. Antimicrobial drug data were analyzed so that drugs were considered unique and distinct based on the World Health Organization (WHO) Anatomical Therapeutic Chemical fifth-level (ie, chemical substance) classification. According to this classification system, most antimicrobial drugs included in the survey were considered unique based on the chemical substance name (eg, ciprofloxacin, azithromycin, clindamycin, etc), without regard to the route of administration. However, for some antimicrobial drugs the enteral and parenteral formulations were considered distinct drugs: vancomycin, metronidazole, colistin, polymyxin B, streptomycin, and neomycin. For example, a patient whose only antimicrobial drugs at the time of the survey were oral and intravenous ciprofloxacin (during an intravenous-to-oral transition day, for example) would be considered to be receiving a single antimicrobial drug because the oral and intravenous formulations of ciprofloxacin are not considered distinct from one another. By contrast, a patient whose only antimicrobial drugs at the time of the survey were oral and intravenous vancomycin would be considered to be receiving 2 antimicrobial drugs because the oral and intravenous formulations of vancomycin are considered distinct.

Antimicrobial drug data were analyzed and reported using WHO Anatomical Therapeutic Chemical fourth-level classifications (the drug subgroup, for example, fluoroquinolones) and fifth-level classifications (the chemical substance name, eg, levofloxacin). The most common individual antimicrobial drugs or drug subgroups administered in particular settings were determined on the basis of the rank order of the point estimates of the proportions of all antimicrobial drugs (or patients). The mid-$P$ exact method was used to generate confidence intervals for antimicrobial use prevalence, defined as the number of patients receiving at least 1 antimicrobial drug divided by the total number of surveyed patients, and for other proportions. Categorical and continuous variables were compared in patients receiving or not receiving antimicrobial drugs using the $\chi^2$ and median tests, respectively. Two-sided $P$ values $< .05$ were considered statistically significant.

**Results**

**Hospitals and Patients**

Surveys were conducted in 183 hospitals from May to September 2011. The numbers of hospitals and patients surveyed in each EIP site have been published. Twenty-two of 183 hospitals (12%) were large hospitals, 68 (37%) were medium, and 93 (51%) were small. The median number of patients surveyed per hospital overall was 75 (interquartile range [IQR], 39-75). The median number of patients surveyed in large hospitals was 100 (IQR, 100-100); in medium hospitals 75 (IQR, 75-75); and in small hospitals 40 (IQR, 23-70). Of 11,282 patients, 5,860 (51.9%) met antimicrobial use screening criteria; of these, 5,847 (99.8%) received or were scheduled to receive antimicrobial drugs on the day of the survey or the day before the survey, and 13 (0.2%) met other criteria.

**Prevalence of Antimicrobial Use**

Among the 5,860 patients who met antimicrobial use screening criteria, 5,625 (96.2%) were confirmed to have received 1 or more antimicrobial drugs at the time of the survey. The antimicrobial use prevalence was therefore 49.9% (95% CI, 49.0%-50.9%). Although most patients receiving antimicrobial drugs were outside of critical care units (4,650 patients, 82.5%; 95% CI, 81.5%-83.5%), antimicrobial drug use prevalence was higher in critical care units than in other locations (57.7%, 95% CI, 55.4%-60.0% vs 48.6%, 95% CI, 47.6%-49.6%; $P < .001$; Table 1). A total of 9,967 antimicrobial drug-route combinations were administered. After conforming to WHO Anatomical Therapeutic Chemical fifth-level classifications, 9,865 antimicrobial drug records remained, representing 90 unique antimicrobial drugs. Of 5,625 patients receiving antimicrobial drugs, 2,811 (49.1%; 95% CI, 48.6%-51.2%) were receiving 1 antimicrobial drug; 1,840 (32.7%; 95% CI, 31.4%-33.9%), 2 antimicrobial drugs; 682 (12.1%; 95% CI, 11.3%-13.0%), 3 antimicrobial drugs; and 302 patients (5.4%; 95% CI, 4.8%-6.0%), 4 or more antimicrobial drugs.

Patients receiving antimicrobial drugs were older, with a median age of 62 years (IQR, 44-76 years) compared with 53 years for patients not receiving antimicrobial drugs (IQR, 24-71 years; $P < .001$). Patients receiving antimicrobial drugs were also more likely than patients not receiving antimicrobial drugs to be men, white, in a critical care unit, and in a small hospital (eTable 1 in the Supplement).

**Common Antimicrobial Drugs**

Of the 9,865 antimicrobial drugs used, 1,388 (14.1%) were fluoroquinolones (95% CI, 13.4%-14.8%); 1,213 (12.3%), parenteral glycopeptides (95% CI, 11.7%-13.0%); 1,081 (11.0%), penicillin combinations (95% CI, 10.4%-11.6%); 1,037 (10.5%) third-generation cephalosporins (95% CI, 9.9%-11.1%); and 983 (10.0%), first-generation cephalosporins (95% CI, 9.4%-10.6%; eTable 2 in the Supplement). Of the individual antimicrobial drugs used overall, 1,213 (12%) were parenteral vancomycin (95% CI, 11.7%-12.9%); 913 (9.3%), ceftazolin (95% CI, 8.7%-9.8%); 864 (8.8%), ceftriaxone (95% CI, 8.2%-9.3%); 829 (8.4%), piperacillin-tazobactam (95% CI, 7.9%-9.0%); and 768 (7.8%), levofloxacin (95% CI, 7.3%-8.3%).

**Rationale for Antimicrobial Drug Use**

Overall, of the 5,625 patients receiving antimicrobial drugs, 4,278 (75.9%; 95% CI, 74.8%-77.0%) were receiving them to treat infections; 1,071 (19.0%; 95% CI, 18.0%-20.1%) for surgical prophylaxis; 388 (6.9%; 95% CI, 6.2%-7.6%) for medical prophylaxis; 40 (0.7%; 95% CI, 0.5%-0.9%) for noninfection-related reasons; and 390 (6.9%; 95% CI, 6.3%-7.6%) for no documented rationale. The reasons for use of antimicrobial drugs in selected WHO Anatomical Therapeutic Chemical fourth-level groups are shown in eTable 3 of the Supplement. For most drug groups, infection treatment was the most common reason for use. Surgical prophylaxis was the most common reason for use of first-generation cephalosporins (72.2%; 95% CI, 69.4%-75.0%) and second gen-
ereation cephalosporins (56.7%; 95% CI, 48.0%-65.1%), and medical prophylaxis was the most common reason for use of nucleoside and nucleotide antivirals (48.5%; 95% CI, 41.7%-55.4%). Of the 9865 individual antimicrobial drugs used, 7641 (77.5%; 95% CI 76.6%-78.3%) were given to treat infections, with or without other reasons for use. Eighty-three different individual antimicrobial drugs were used to treat infections. Of those 7641 treatment antimicrobial drugs used, 1229 (16.1%) were fluoroquinolones (95% CI, 15.3%-16.9%); 1104 (14.4%), parenteral glycopeptides (95% CI, 13.7%-15.3%); 1000 (13.1%), penicillin combinations (95% CI, 12.3%-13.9%); and 983 (12.9%), third-generation cephalosporins (95% CI, 12.1%-13.6%).

Surgical prophylaxis was reported as a rationale for 1199 antimicrobial drugs (12.2%; 95% CI, 11.5%-12.8%), with or without other reasons for use. Five of 35 different antimicrobial drugs accounted for more than 80% of drugs given for surgical prophylaxis: 715, cefazolin (59.6%; 95% CI, 56.8%-62.4%); 91, parenteral vancomycin (7.6%; 95% CI, 6.2%-9.2%); 77, clindamycin (6.4%; 95% CI, 5.1%-7.8%); 44, parenteral metronidazole (3.7%; 95% CI, 2.7%-4.9%); and 43, cefoxitin (3.6%; 95% CI, 2.6%-4.8%).

Medical prophylaxis was reported as a rationale for 583 antimicrobial drugs (5.9%; 95% CI, 5.5%-6.4%), with or without other reasons for use. A total of 54 different antimicrobial drugs were administered for medical prophylaxis, although 5 antimicrobial drugs accounted for almost half of those used for medical prophylaxis: 69 (11.5%) of 583 were acyclovir (95% CI, 9.4%-14.7%); 67 (11.5%), trimethoprim-sulfamethoxazole (11.5%; 95% CI, 9.1%-14.3%); 56 (9.6%), benzylpenicillin (95% CI, 7.4%-12.2%); 51 (8.8%), fluconazole (95% CI, 6.7%-11.3%); and 32 (5.5%), azithromycin (95% CI, 3.8%-7.6%).

Fifty-seven of 69 patients receiving prophylactic acyclovir (82.6%; 95% CI, 72.3%-90.2%) and 30 of 51 patients receiving prophylactic fluconazole (58.8%; 95% CI, 45.0%-71.7%) were located in hematology/oncology, hematopoietic stem cell transplant, or solid organ transplant units. Fifty-three of 56 patients (94.6%) receiving prophylactic benzylpenicillin were in obstetrical care locations (95% CI, 86.1%-98.6%).

A noninfection-related rationale for use was reported for 41 antimicrobial drugs (0.4%; 95% CI, 0.30%-0.56%; eTable 4 in the Supplement). No rationale could be identified in the medical record for 455 antimicrobial drugs (4.6%; 95% CI, 4.2%-5.0%; eTable 5 in the Supplement).

**Antimicrobial Drugs Administered to Treat Infections**

Of all antimicrobial drugs used to treat infections, 2607 (34.1%) were for lower respiratory tract (95% CI, 33.1%-35.2%), 1302...
Table 2. Infection Sites for Which Patients Received Antimicrobial Treatment

<table>
<thead>
<tr>
<th>Infection Site</th>
<th>No. of Drugs, (%) [95% CI] (n = 7641)</th>
<th>No. of Patients, (%) [95% CI] (n = 4278)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower respiratory tract</td>
<td>2607 (34.1) [33.1-35.2]</td>
<td>1480 (34.6) [33.2-36.0]</td>
</tr>
<tr>
<td>Urinary tract</td>
<td>1302 (17.0) [16.2-17.9]</td>
<td>955 (22.3) [21.1-23.6]</td>
</tr>
<tr>
<td>Skin and soft tissue</td>
<td>1177 (15.4) [14.6-16.2]</td>
<td>688 (16.1) [15.0-17.2]</td>
</tr>
<tr>
<td>Gastrointestinal tract</td>
<td>829 (10.8) [10.2-11.6]</td>
<td>537 (12.6) [11.6-13.6]</td>
</tr>
<tr>
<td>Undetermined/empirical</td>
<td>661 (8.7) [8.0-9.3]</td>
<td>364 (8.5) [7.7-9.4]</td>
</tr>
<tr>
<td>Bloodstream</td>
<td>639 (8.4) [7.8-9.0]</td>
<td>401 (9.4) [8.5-10.3]</td>
</tr>
<tr>
<td>Intra-abdominal</td>
<td>317 (4.1) [3.7-4.6]</td>
<td>178 (4.2) [3.6-4.8]</td>
</tr>
<tr>
<td>Bone and joint</td>
<td>291 (3.8) [3.4-4.3]</td>
<td>185 (4.3) [3.7-5.0]</td>
</tr>
<tr>
<td>Ear, nose, and throat</td>
<td>237 (3.1) [2.7-3.5]</td>
<td>183 (4.3) [3.7-4.9]</td>
</tr>
<tr>
<td>Hepatobiliary system</td>
<td>183 (2.4) [2.1-2.8]</td>
<td>109 (2.5) [2.1-3.1]</td>
</tr>
<tr>
<td>Central nervous system</td>
<td>137 (1.8) [1.5-2.1]</td>
<td>76 (1.8) [1.4-2.2]</td>
</tr>
<tr>
<td>Cardiovascular system</td>
<td>82 (1.1) [0.9-1.3]</td>
<td>50 (1.2) [0.9-1.5]</td>
</tr>
<tr>
<td>Reproductive tract</td>
<td>80 (1.0) [0.8-1.3]</td>
<td>46 (1.1) [0.8-1.4]</td>
</tr>
<tr>
<td>Disseminated</td>
<td>47 (0.6) [0.5-0.8]</td>
<td>38 (0.9) [0.6-1.2]</td>
</tr>
<tr>
<td>Unknown</td>
<td>34 (0.4) [0.3-0.6]</td>
<td>27 (0.6) [0.4-0.9]</td>
</tr>
<tr>
<td>Other</td>
<td>5 (0.07) [0.02-0.15]</td>
<td>3 (0.07) [0.02-0.19]</td>
</tr>
</tbody>
</table>

*Antimicrobial drugs could be given for more than one infection site.

Table 3. Five Most Common Antimicrobial Drugs Given to Treat Community-Onset Infections and Health Care Facility-Onset Infections

<table>
<thead>
<tr>
<th>Rank</th>
<th>Community-Onset Infectionsb (n = 5274)</th>
<th>Health Care Facility-Onset Infectionsc (n = 2220)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vancomycin: 723 (13.7) [12.8-14.7]d</td>
<td>Vancomycin: 354 (15.9) [14.5-17.5]d</td>
</tr>
<tr>
<td>2</td>
<td>Ceftriaxone: 671 (12.7) [11.8-13.6]</td>
<td>Piperacillin-tazobactam: 259 (11.7) [10.4-13.1]</td>
</tr>
<tr>
<td>3</td>
<td>Levofloxacin: 518 (9.8) [9.0-10.7]</td>
<td>Levofloxacin: 170 (7.7) [6.6-8.8]</td>
</tr>
<tr>
<td>4</td>
<td>Piperacillin-tazobactam: 516 (9.8) [9.0-10.6]</td>
<td>Ceftriaxone: 147 (6.6) [5.6-7.7]</td>
</tr>
<tr>
<td>5</td>
<td>Azithromycin: 342 (6.5) [5.8-7.2]</td>
<td>Metronidazole: 101 (4.5) [3.7-5.5]e</td>
</tr>
</tbody>
</table>

*Antimicrobial drugs could be given for more than one infection site.

(17.0%) for urinary tract infections (95% CI, 16.2%-17.9%), 1177 (15.4%) for skin and soft tissue infections (95% CI, 14.6%-16.2%), and 829 (10.8%) for gastrointestinal tract infections (95% CI, 10.2%-11.6%) and 661 (8.7%) for infections of undetermined site, including empirical therapy for suspected infection (95% CI, 8.0%-9.3%; Table 2). Of the 7641 antimicrobial drugs given to treat infections, 4154 (54.4%); 95% CI, 53.3%-55.5%) were given to treat lower respiratory tract-only infections, urinary tract-only infections, or skin and soft tissue-only infections. Of the 7641 antimicrobial drugs given to treat infections, the most common were parenteral vancomycin (1103, 14.4%); 95% CI, 13.7%-15.2%); ceftriaxone (825, 10.8%); 95% CI, 10.1%-11.5%); piperacillin-tazobactam (788, 10.3%); 95% CI, 9.6%-11.0%); levofloxacin (694, 9.1%); 95% CI, 8.5%-9.7%); and azithromycin (390, 5.1%); 95% CI, 4.6%-5.6%). Piperacillin-tazobactam and vancomycin (parenteral or oral/enteral) ranked among the top 5 antimicrobial drugs for each of the 5 most common infection sites. Fluoroquinolones (levofloxacin or ciprofloxacin) ranked among the top 5 antimicrobial drugs for 4 of the 5 most common infection sites. Fluoroquinolones were not among the top-ranked antimicrobial drugs for treating skin and soft tissue infections (eTable 6 in the Supplement).

Of antimicrobial treatment was for community-onset infections. Of the 4278 patients receiving 7641 antimicrobial drugs to treat infections, 3058 patients (71.5%); 95% CI, 70.1%-72.8%) were receiving 5274 antimicrobial drugs (69.0%); 95% CI, 68.0%-70.1%) for community-onset infections; 1253 patients (29.3%); 95% CI, 27.9%-30.7%) were receiving 2220 antimicrobial drugs (29.1%); 95% CI, 28.0%-30.1%) for health care facility-onset infections, and 99 patients (2.3%); 95% CI, 1.9%-2.8%) were receiving 147 antimicrobial drugs (2.0%); 95% CI, 1.7%-2.3%) for infections with different onset locations, unknown onset location, or both. Treatments for community-onset and health care facility-onset infections were similar: parenteral vancomycin, ceftriaxone, piperacillin-tazobactam, and levofloxacin were among the 5 most commonly administered antimicrobial drugs for both community-onset and health care facility-onset infections (Table 3).
Parenteral vancomycin, ceftriaxone, piperacillin-tazobactam, and levofloxacin were also among the 5 most common drugs overall given to patients in critical care and noncritical care units (Table 4). These 4 drugs were among the 5 most common drugs given for community-onset infections in both critical care and noncritical care locations (excluding neonatal locations), and for health care facility-onset infections in noncritical care locations (excluding neonatal locations; Table 5). Parenteral vancomycin, piperacillin-tazobactam, and levofloxacin, but not ceftriaxone, were among the top 5 drugs given to treat health care facility-onset infections in nonneonatal critical care units. Among antimicrobial drugs given to treat only the most common infection site, community-onset lower respiratory tract infections, these 4 drugs plus azithromycin were the 5 most commonly administered both inside and outside of critical care units (Table 7 in the Supplement). Parenteral vancomycin and piperacillin-tazobactam made up approximately 15.3% (991 of 1248; 95% CI, 13.4%-17.4%) of all antimicrobial drugs given to treat community-onset lower respiratory tract infections in nonneonatal, noncritical care units compared with 27.6% of drugs given to treat community-onset lower respiratory tract infections in neonatal care units (95% CI, 23.2%-32.4%; P < .001, \( \chi^2 \) test).

### Table 4. Five Most Common Antimicrobial Drugs Given to Patients Receiving Antimicrobial Drugs to Treat Infections in Critical Care and Noncritical Care Locations

<table>
<thead>
<tr>
<th>Rank</th>
<th>Critical Care Locations (n = 788) No. of Patients, (%) [95% CI]</th>
<th>Non–Critical Care Locations (n = 3490) No. of Patients, (%) [95% CI]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vancomycin: 275 (34.9) [31.6-38.3]*</td>
<td>Vancomycin: 828 (23.7) [22.3-25.2]*</td>
</tr>
<tr>
<td>2</td>
<td>Piperacillin-tazobactam: 202 (25.6) [22.7-28.8]</td>
<td>Ceftriaxone: 705 (20.2) [18.9-21.6]</td>
</tr>
<tr>
<td>3</td>
<td>Levofloxacin: 133 (16.9) [14.4-19.6]</td>
<td>Piperacillin-tazobactam: 586 (16.8) [15.6-18.1]</td>
</tr>
<tr>
<td>4</td>
<td>Ceftriaxone: 120 (15.2) [12.9-17.9]</td>
<td>Levofloxacin: 561 (16.1) [14.9-17.3]</td>
</tr>
<tr>
<td>5b</td>
<td>Gentamicin: 65 (8.2) [6.5-10.3]</td>
<td>Ciprofloxacin: 339 (9.7) [8.8-10.7]</td>
</tr>
</tbody>
</table>

* Parenteral formulation of the drug.
* When neonatal critical care units were excluded, parenteral metronidazole was the fifth most commonly administered antimicrobial drug (8.7% of 691 patients receiving antimicrobial drugs to treat infections in nonneonatal critical care units [95% CI, 6.8%-10.0%]). There was no change in rankings of antimicrobial drugs given to patients receiving infection treatment in noncritical care units when neonatal units were excluded.

### Table 5. Five Most Common Antimicrobial Drugs for Treatment of Community-Onset and Health Care Facility-Onset Infections in Nonneonatal Critical Care and Noncritical Care Locations

<table>
<thead>
<tr>
<th>Rank</th>
<th>Community-Onset Infectionsa No. of Drugs, (%) [95% CI]</th>
<th>Health Care Facility-Onset Infectionsb No. of Drugs, (%) [95% CI]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vancomycin: 141 (16.7) [14.3-19.3]†</td>
<td>Vancomycin: 102 (18.3) [15.3-21.7]†</td>
</tr>
<tr>
<td>2</td>
<td>Piperacillin-tazobactam: 113 (13.4) [12.3-14.3]†</td>
<td>Piperacillin-tazobactam: 85 (15.3) [10.3-13.6]</td>
</tr>
<tr>
<td>3</td>
<td>Ceftriaxone: 98 (11.6) [9.6-13.9]</td>
<td>Levofloxacin: 39 (7.0) [5.1-9.4]</td>
</tr>
<tr>
<td>4</td>
<td>Levofloxacin: 92 (10.9) [8.9-13.1]</td>
<td>Fluconazole: 35 (6.3) [4.5-8.5]</td>
</tr>
<tr>
<td>5</td>
<td>Azithromycin: 50 (5.8) [4.5-7.7]</td>
<td>Ceftriaxone: 126 (8.6) [7.3-10.2]</td>
</tr>
</tbody>
</table>

* Antimicrobial drugs are included if they were identified as being given for treatment of community-onset infections. Community-onset infections were defined as infections for which signs or symptoms began in community settings (eg, private residences, assisted living facilities, correctional facilities, homeless shelters, halfway houses, substance abuse rehabilitation facilities, etc).
* Antimicrobial drugs are included if they were identified as being given for treatment of health care facility-onset infections. Health care facility-onset infections were defined as infections for which signs or symptoms began in the survey hospital or in another health care facility (eg, another acute care hospital, long term care facility, outpatient dialysis center or infusion center, etc.) prior to transfer to the survey hospital.

* Parenteral formulation of the drug.

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### Discussion

Antimicrobial drug use was in this prevalence survey conducted in US acute care hospitals. Approximately 50% of patients were receiving antimicrobial drugs at the time of the survey, and of those, approximately 50% were receiving 2 or more antimicrobial drugs. Similar to older reports, most antimicrobial use was for infection treatment. Although there were 83 different antimicrobial drugs administered to treat infections, just 4—parenteral vancomycin, piperacillin-tazobactam, ceftriaxone, and levofloxacin—made up approximately 45% of all antimicrobial drug treatment. These 4 drugs were not only the most common drugs for treating health care...
facility-onset infections and for treating patients in critical care units but were also the most common drugs for treating community-onset infections and patients outside of the critical care setting (Table 3 and Table 4). Additionally, approximately 54% of treatment antimicrobial drugs were given to treat lower respiratory tract, urinary tract, or skin and soft tissue infections only. Taken together, focusing stewardship efforts on these 4 drugs and 3 infection syndromes could address more than half of all inpatient antimicrobial drug use.

Parenteral vancomycin, the most common antimicrobial drug overall, was given to approximately 1 in 4 surveyed patients receiving infection treatment. The emergence of methicillin-resistant Staphylococcus aureus (MRSA) as a dominant pathogen in health care and community settings, coupled with increased awareness among health care professionals and the public, likely accounts in part for the high prevalence of vancomycin use. However, recent data suggest that the incidence of health care-associated invasive MRSA infections is declining. Data from the health care-associated infection component of our survey showed that a relatively low proportion of infections were caused by MRSA or coagulase-negative staphylococci, the most common bacteria for which vancomycin would appropriately be prescribed: 10.7% were due to S. aureus, with approximately 55% of tested S. aureus isolates reported to be MRSA, and 4.8% were due to coagulase-negative staphylococci. Although rates of community-associated invasive MRSA infections have improved only slightly in recent years, it is worth considering whether inpatient vancomycin use can be reduced in selected circumstances without compromising patient safety. Investigators have developed scoring systems and other methods to help identify patients likely to be infected with MRSA. Implementing such tools and promoting discontinuation of vancomycin therapy when diagnostic results do not indicate a need for use have the potential to reduce unnecessary prescribing.

Another area with potential for improvement is treatment of lower respiratory tract infections. The most common drugs administered for these infections in this survey, levofloxacin, azithromycin, and ceftriaxone, are consistent with current guidelines for management of community-acquired pneumonia in adults. However, parenteral vancomycin and piperacillin-tazobactam were also frequently used to treat lower respiratory tract infections. Although these drugs are recommended for community-acquired pneumonia treatment in selected critically ill patients, they made up a substantial proportion of the antimicrobial drugs given to patients in noncritical care locations to treat community-onset infections. This suggests that therapy outside critical care units may be an area for further evaluation and assessment of the need for intervention: for example, using patient risk factors and results of timely diagnostic testing to inform appropriate antibiotic selection and tailoring, and taking antibiotic time-outs to reassess the need for ongoing treatment. Studies have shown that antimicrobial treatment for hospitalized patients with community-acquired pneumonia can be significantly improved through stewardship interventions.

Although our data suggest that potential misuse of antimicrobial drugs for active infections in hospitalized patients may be common, antimicrobial drugs given only for surgical prophylaxis in our survey were largely consistent with current guidelines. The national Surgical Care Improvement Project has focused on improving antibiotic prophylaxis selection and discontinuing prophylaxis within 24 hours, and data on both of these performance measures indicate high levels of adherence among US acute care hospitals submitting data to the Joint Commission. Despite the reported high levels of compliance with these measures and data showing national progress in preventing surgical site infections related to certain types of procedures, there is room for improvement. Surgical site infections remain among the most common types of health care-associated infections, and data on their pathogens and antimicrobial resistance suggest the potential need to reevaluate surgical antimicrobial prophylaxis recommendations. Other studies have shown that reported adherence with individual Surgical Care Improvement Project antimicrobial prophylaxis measures was not associated with lower surgical site-infection rates or successful adherence to all measures, suggesting that addressing barriers to correct implementation of surgical site infection prevention measures may also be important.

Antimicrobials for medical prophylaxis were prescribed to a smaller population of surveyed patients than surgical prophylaxis. The most common medical prophylaxis antimicrobial drugs were drugs that are appropriately used to prevent infections in specific circumstances. We did not collect data on patients’ underlying conditions, but information about the hospital locations of patients receiving medical prophylaxis suggests these antimicrobial drugs were generally used in appropriate settings. For example, penicillin G is one of the recommended antimicrobial drugs for prevention of perinatal group B streptococcal disease, and almost 95% of all benzylpenicillin prophylaxis in this survey was administered to patients in obstetrical locations.

This survey has several limitations. Because we assessed antimicrobial use over a 2-day period, longer antibiotic courses may be overrepresented relative to short courses. The survey’s restriction to 183 hospitals in 10 states limits the generalizability of the results, although to our knowledge, it is among the largest inpatient antimicrobial use evaluations in the United States to date. The survey was conducted in 2011, and it is unknown whether the prevalence or patterns of antimicrobial use are similar or different in hospitals today. Because we relied on clinician documentation rather than applying specific, objective criteria to identify infections, we may have overestimated the proportion of antimicrobial drugs given to treat infections. We also collected information on locations of infection onset rather than locations to which infections were attributed, so it is likely that some antimicrobial drugs categorized in the community-onset group were given to treat infections that were health care facility-associated but began in the community (eg, surgical site infection developing while the patient was at home recovering from surgery). This might have minimized differences between antimicrobial drugs for community-onset and health care facility-onset infections. Finally, we did not collect information on treatment duration or on patients’ diagnoses and underlying conditions and there-
fore were unable to determine whether antimicrobial use was correct in individual patients. We are exploring methods to evaluate the quality of antimicrobial prescribing and plan to incorporate these in future investigations.

To minimize patient harm and preserve effectiveness, it is imperative to critically examine and improve the ways in which antimicrobial drugs are used. Improving antimicrobial use in hospitals benefits individual patients and also contributes to reducing antimicrobial resistance nationally. The CDC has described the core elements of effective hospital antimicrobial stewardship programs. One of these core elements is “tracking and reporting antibiotic use and outcomes.” Prospective surveillance to track antimicrobial consumption is important for evaluating progress in reducing incorrect inpatient antimicrobial use. The NHSN recently launched an antimicrobial use reporting option to which health care facilities can electronically report monthly antimicrobial drug consumption data from different inpatient locations to facilitate risk-adjusted benchmarking and guide stewardship efforts.

Another core element is “implementing policies and interventions to improve antibiotic use.” Results from this prevalence survey provide patient-level information that augments data on antimicrobial drug consumption and points to specific areas where interventions to improve antimicrobial use may be needed, such as vancomycin prescribing and respiratory infection treatment, supporting the CDC’s recommendation that every acute care hospital implement an antimicrobial stewardship program.

Conclusions

In this cross-sectional evaluation of antimicrobial use in US hospitals, use of broad-spectrum antimicrobial drugs such as piperacillin-tazobactam and drugs such as vancomycin for resistant pathogens was common, including for treatment of community-onset infections and among patients outside critical care units. Further work is needed to understand the settings and indications for which reducing antimicrobial use can be most effectively and safely accomplished.
Research Original Investigation

Antimicrobial Use in Acute Care Hospitals

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Correction: This article was corrected on October 7, 2014, to include a link to eTable 7 in the Supplement.

REFERENCES


