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Prevalence of Antimicrobial Use in U.S. Acute Care Hospitals, May–September 2011

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Abstract

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 healthcare settings.

Main Outcome and Measure—Antimicrobial use prevalence, defined as the number of patients on 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 ≥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, while 12.2% (95% CI, 11.5%–12.8%) and 5.9% (95% CI, 5.5%–6.4%) were given for surgical and medical prophylaxis, respectively. 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 healthcare 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 U.S. 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.

Introduction

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 U.S. acute care hospitals may be inappropriate, based on factors such as lack of indication or incorrect drug selection, dosing or 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 for 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 U.S. hospitals, it is necessary to understand inpatient antimicrobial use epidemiology. There have been few large-scale efforts to define antimicrobial use epidemiology in U.S. 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 data from 2002–2006.[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 multi-state, acute care hospital antimicrobial use prevalence survey in 2011 to determine the prevalence of inpatient antimicrobial use, the most common antimicrobial drugs, and the reasons for their use.

METHODS

Hospital and patient selection

The antimicrobial use survey was performed in conjunction with a survey of healthcare-associated infections (HAIs) 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 set 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 where a selected hospital declined to participate.

Each hospital performed a one-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, while small and medium hospitals surveyed either 75 patients or all eligible acute care inpatients if the census was <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 HAI 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 (Supplement, eMethods1) at the time of the survey, using the following screening criteria: 1) the patient was administered or was scheduled to be administered ≥1 antimicrobial drug on the survey date or the calendar day prior to the survey date; 2) the patient was a dialysis patient 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 information was unknown or not available at the time of the survey. Topical antimicrobials were excluded. 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 to dialysis patients during the 4 calendar days prior to the survey date. 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 two times for a given patient, if that antimicrobial drug was administered via two different routes at the time of the survey (e.g., 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 non-infection-related reason, or unknown rationale. Empiric use of antimicrobial drugs for suspected infection was considered treatment. Non-infection 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 healthcare facility, or community) based on clinician documentation in the medical record. While National Healthcare Safety Network (NHSN) HAI surveillance definitions were used in the HAI portion of the survey,[18] 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, Inc., Cary, NC) and OpenEpi version 3.01.[19] Antimicrobial drug data were analyzed so that drugs were considered unique and distinct based upon the World Health Organization (WHO) Anatomical Therapeutic Chemical (ATC) 5th-level (i.e., chemical substance) classification. According to this classification system, most antimicrobial drugs included in the survey were considered unique based on the chemical substance name (e.g., 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, amphotericin B, streptomycin, and neomycin.[20,21] 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 on 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 on two antimicrobial drugs, because the oral and intravenous formulations of vancomycin are considered distinct.

Antimicrobial drug data were analyzed and reported using WHO ATC 4th level classifications (the drug subgroup, for example, “fluoroquinolones”) and 5th level classifications (the chemical substance name, for example, “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 (CIs) for antimicrobial use prevalence, defined as the number of patients receiving ≥1 antimicrobial drug divided by the total number of surveyed patients, and for other proportions. Categorical and continuous variables were compared in patients on antimicrobial drugs and not on antimicrobial drugs using chi-square and median tests, respectively. Two-sided *P*-values <0.05 were considered statistically significant.

RESULTS

Hospitals and patients

Surveys were conducted in 183 hospitals from May to September 2011. Numbers of hospitals and patients surveyed in each EIP site have been published.[18] 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 (interquartile range [IQR] 100–100); in medium hospitals 75 (IQR 75–75); and in small hospitals 40 (IQR 23–70). Of 11,282 patients, 5860 (51.9%) met antimicrobial use screening criteria; of these, 5847 (99.8%) received or were scheduled to receive ADs on the day of the survey or the day prior to the survey, and 13 (0.2%) met other criteria.

Prevalence of antimicrobial use

Among the 5860 patients who met antimicrobial use screening criteria, 5635 (96.2%) were confirmed to have received ≥1 antimicrobial drug at the time of the survey. The antimicrobial use prevalence was therefore 49.9% (95% CI, 49.0%–50.9%). Although most patients on antimicrobial drugs were outside of critical care units (4650 patients, 82.5%; 95% CI, 81.5%–83.5%), antimicrobial 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%], $P<0.001$) (Table 1).

A total of 9967 antimicrobial drug/route combinations were administered. After conforming to WHO ATC 5th level classifications, 9865 antimicrobial drugs records remained, representing 90 unique antimicrobial drugs. Of 5635 patients on antimicrobial drugs, 2811 (49.9%; 95% CI, 48.6%–51.2%) were receiving 1 antimicrobial drug, 1840 (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 antimicrobial drugs.

Patients on antimicrobial drugs were older, with a median age of 62 years (IQR 44–76 years), as compared to 53 years for patients not on antimicrobial drugs (IQR 24–71 years) ($P<0.001$). Patients on antimicrobial drugs were also more likely than patients not on antimicrobial drugs to be male, white, in a critical care unit, and in a small hospital (Supplement, eTable 1).

Common antimicrobial drugs

The most common WHO ATC 4th level antimicrobial drug groups were fluoroquinolones (1388, 14.1% of a total of 9865 antimicrobial drugs; 95% CI, 13.4%–14.8%), parenteral glycopeptides (1213, 12.3%; 95% CI, 11.7%–13.0%), penicillin combinations (1081, 11.0%; 95% CI, 10.4%–11.6%), 3rd generation cephalosporins (1037, 10.5%; 95% CI, 9.9%–11.1%), and 1st generation cephalosporins (983, 10.0%; 95% CI, 9.4%–10.6%) (Supplement, eTable 2). The most common individual antimicrobial drugs overall were parenteral vancomycin (1212, 12.3%; 95% CI, 11.7%–12.9%), cefazolin (913, 9.3%; 95% CI, 8.7%–9.8%), ceftriaxone (864, 8.8%; 95% CI, 8.2%–9.3%), piperacillin/tazobactam (829, 8.4%; 95% CI, 7.9%–9.0%), and levofloxacin (768, 7.8%; 95% CI, 7.3%–8.3%).

Rationale for antimicrobial drug use

Overall, 4278 of 5635 patients (75.9% of patients on antimicrobial drugs; 95% CI, 74.8%–77.0%) were receiving antimicrobial drugs to treat infections; 1071 (19.0%; 95% CI, 18.0%–20.1%) for surgical prophylaxis; 388 (6.9%; 95% CI, 6.2%–7.6%) for medical prophylaxis; 40 (0.71%; 95% CI, 0.51%–0.96%) for non-infection-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 ATC 4th level groups are shown in the Supplement (eTable 3). For most drug groups, infection treatment was the most common reason for use. Exceptions included the 1st and 2nd generation cephalosporins, for which surgical prophylaxis was the most common reason for use (72.2%; 95% CI, 69.4%–75.0%, and 56.7%; 95% CI, 48.0%–65.1%, respectively), and the nucleoside and

nucleotide antivirals, for which medical prophylaxis was the most common reason for use (48.5%; 95% CI, 41.7%–55.4%). Most individual antimicrobial drugs (7641 of 9865, 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. Among the 7641 treatment antimicrobial drugs, the most common were fluoroquinolones (1229, 16.1%; 95% CI, 15.3%–16.9%), parenteral glycopeptides (1104, 14.4%; 95% CI, 13.7%–15.3%), penicillin combinations (1000, 13.1%; 95% CI, 12.3%–13.9%), and 3rd generation cephalosporins (983, 12.9%; 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: cefazolin (715, 59.6%; 95% CI, 56.8%–62.4%), parenteral vancomycin (91, 7.6%; 95% CI, 6.2%–9.2%), clindamycin (77, 6.4%; 95% CI, 5.1%–7.9%), parenteral metronidazole (44, 3.7%; 95% CI, 2.7%–4.9%), and cefoxitin (43, 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 all medical prophylaxis: acyclovir (69 of 583 antimicrobial drugs, 11.8%; 95% CI, 9.4%–14.7%), trimethoprim/sulfamethoxazole (67, 11.5%; 95% CI, 9.1%–14.3%), benzylpenicillin (56, 9.6%; 95% CI, 7.4%–12.2%), fluconazole (51, 8.8%; 95% CI, 6.7%–11.3%), and azithromycin (32, 5.5%; 95% CI, 3.8%–7.6%). Patients receiving prophylactic acyclovir and fluconazole were located predominantly in hematology/oncology, hematopoietic stem cell transplant, and solid organ transplant units (57/69, 82.6% [95% CI, 72.3%–90.2%], and 30/51, 58.8% [95% CI, 45.0%–71.7%], respectively). Most patients receiving prophylactic benzylpenicillin were in obstetrical care locations (53/56, 94.6%; 95% CI, 86.1%–98.6%).

A non-infection-related rationale for use was reported for 41 antimicrobial drugs (0.42%; 95% CI, 0.30%–0.56%) (Supplement, eTable 4). No rationale could be identified in the medical record for 455 antimicrobial drugs (4.6%; 95% CI, 4.2%–5.0%) (Supplement, eTable 5).

Antimicrobial drugs administered to treat infections

The most common infection sites for which antimicrobial drugs were given were lower respiratory (LRI, 2607, 34.1% [95% CI, 33.1%–35.2%] of all antimicrobial drugs given to treat infections), urinary tract (UTI, 1302, 17.0%; 95% CI, 16.2%–17.9%), skin and soft tissue (SSTI, 1177, 15.4%; 95% CI, 14.6%–16.2%), gastrointestinal tract (829, 10.8%; 95% CI, 10.2%–11.6%), and infections of undetermined site, including empiric therapy for suspected infection (661, 8.7%; 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 LRI alone, UTI alone, or SSTI alone.

The most common individual antimicrobial drugs given to treat infections were parenteral vancomycin (1103 of 7641 treatment antimicrobial drugs, 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 (not SSTI) (Supplement, eTable 6).

Most 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 healthcare 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 and/or unknown onset location. Treatments for community-onset and healthcare facility-onset infections were similar: parenteral vancomycin, ceftriaxone, piperacillin/tazobactam, and levofloxacin were among the 5 most common antimicrobial drugs for both community-onset and healthcare 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 non-critical care units (Table 4). These 4 drugs were among the 5 most common drugs given for community-onset infections in both critical care and non-critical care locations (excluding neonatal locations), and for healthcare facility-onset infections in non-critical 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 healthcare facility-onset infections in non-neonatal, 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 (eTable 7 in the Supplement). Parenteral vancomycin and piperacillin/tazobactam made up approximately 15.3% (191/1248; 95% CI, 13.4%–17.4%) of all antimicrobial drugs given to treat community-onset LRI in non-neonatal, non-critical care units, as compared to 27.6% of drugs given to treat community-onset LRI in non-neonatal, critical care units (101/366; 95% CI, 23.2%–32.4%, $P<0.001$, chi-square test).

DISCUSSION

Antimicrobial drug use was common in this prevalence survey in U.S. 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 antimicrobial drugs. Similar to older reports,[22,23] most antimicrobial use was for infection treatment. Although there were 83 different antimicrobial drugs administered to treat infections, just four—parenteral vancomycin, piperacillin/tazobactam, ceftriaxone, and levofloxacin—made up approximately 45% of all antimicrobial drug treatment. These four drugs were not only the

most common drugs for treating healthcare 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. Additionally, approximately 54% of treatment antimicrobial drugs were given solely to treat LRIs, UTIs, or SSTIs. Taken together, focusing stewardship efforts on these four drugs and three infection syndromes could address more than half of all inpatient antimicrobial use.

Parenteral vancomycin, the most common antimicrobial drug overall, was given to more than one in four surveyed patients receiving infection treatment. The emergence of methicillin-resistant *Staphylococcus aureus* (MRSA) as a dominant pathogen in healthcare and community settings, coupled with increased awareness among healthcare providers and the public, likely accounts in part for the high prevalence of vancomycin use. However, recent data suggest that the incidence of healthcare-associated invasive MRSA infections is declining.[24] Data from the HAI component of our survey[18] showed that a relatively low proportion of HAIs were caused by MRSA or coagulase-negative staphylococci, the most common bacteria for which vancomycin would appropriately be prescribed: 10.7% of HAIs were due to *S. aureus*, with approximately 55% of tested *S. aureus* isolates reported to be MRSA, and 4.8% of HAIs were due to coagulase-negative staphylococci. Although rates of community-associated invasive MRSA infections have improved only slightly in recent years,[24] 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.[25–27] 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 LRI. The most common drugs administered for LRI in this survey, levofloxacin, azithromycin, and ceftriaxone, are consistent with current guidelines for management of community-acquired pneumonia (CAP) in adults.[28] However, parenteral vancomycin and piperacillin/tazobactam were also frequently used to treat LRI. While these drugs are recommended for CAP treatment in selected critically ill patients,[28] they made up a substantial proportion of the antimicrobial drugs given to patients in non-critical care locations to treat community-onset LRI. This suggests that therapy of LRI 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” [6] to reassess the need for ongoing treatment. Studies have shown that antimicrobial treatment for hospitalized patients with CAP can be significantly improved through stewardship interventions.[29,30]

While 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.[31] The national Surgical Care Improvement Project (SCIP) 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 compliance among U.S. acute care hospitals

submitting data to The Joint Commission.[32] Despite the reported high levels of compliance with these measures and data showing national progress in preventing surgical site infections (SSIs) related to certain types of procedures,[33] there is room for improvement. Surgical site infections remain among the most common types of HAIs,[18] and data on SSI pathogens and antimicrobial resistance[34] suggest the potential need to reevaluate surgical antimicrobial prophylaxis recommendations. Other studies have shown that reported compliance with individual SCIP antimicrobial prophylaxis measures was not associated with lower SSI rates[35] or successful adherence to all measures,[36] suggesting that addressing barriers to correct implementation of SSI 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, current guidelines recommend penicillin G for prevention of perinatal group B streptococcal infection,[37] 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 two-day period, longer antibiotic courses may be over-represented 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 healthcare facility-associated but began in the community (e.g., 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 healthcare facility-onset infections. Finally, we did not collect information on treatment duration or on patients' diagnoses and underlying conditions, and therefore 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. Reducing unnecessary antimicrobial use in hospitals benefits individual patients and also contributes to reducing antimicrobial resistance nationally.[13] CDC has described the core elements of effective hospital antimicrobial stewardship programs.[38] One of these core elements is "tracking and reporting antibiotic use and outcomes." [38] Prospective surveillance to

track antimicrobial consumption is important for evaluating progress in reducing incorrect inpatient antimicrobial use.[39] The NHSN recently launched an antimicrobial use reporting option to which healthcare facilities can electronically report monthly antimicrobial drug consumption data from different inpatient locations to facilitate risk adjusted benchmarking and guide stewardship efforts.[40] Another core element is "implementing policies and interventions to improve antibiotic use." [38] 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 CDC's recommendation that every acute care hospital implement an antimicrobial stewardship program.[38]

CONCLUSIONS

In this cross-sectional evaluation of antimicrobial use in U.S. 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.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Antimicrobial use prevalence in different hospital locations.[a,b]

Location [b]	Total no. of patients	No. of patients on antimicrobial drugs	Prevalence, *percent*	95% confidence interval
Surgical critical care unit	88	68	77.3	67.7 – 85.1
Medical/surgical pediatric critical care unit	66	47	71.2	59.5 – 81.2
Cardiothoracic critical care unit	75	51	68.0	56.8 – 77.8
Medical/surgical critical care unit	639	426	66.7	62.9 – 70.2
Medical critical care unit	243	156	64.2	58.0 – 70.0
Orthopedic ward	480	287	59.8	55.4 –64.1
Medical ward	1618	918	56.7	54.3 – 59.1
Medical/surgical ward	2612	1475	56.5	54.6 – 58.4
Cardiac critical care unit	50	28	56.0	42.1 – 69.2
Mixed acuity adult unit	106	59	55.7	46.1 – 64.9
Hematology/oncology pediatric specialty care area	54	29	53.7	40.4 – 66.6
Surgical ward	919	487	53.0	49.8 – 56.2
Hematology/oncology specialty care area	314	165	52.6	47.0 – 58.0
Stepdown unit	445	231	51.9	47.3 – 56.5
Medical/surgical pediatric ward	241	124	51.5	45.1 – 57.7
Medical pediatric ward	108	55	50.9	41.5 – 60.3
Telemetry ward	758	325	42.9	39.4 – 46.4
Gynecology ward	59	25	42.4	30.3 – 55.2
Neurosurgical critical care unit	52	21	40.4	27.7 – 54.1
Neonatal critical care unit level III	240	81	33.8	28.0 – 39.9
Neurology ward	77	25	32.5	22.7 – 43.5
Neonatal critical care unit level II/III	145	47	32.4	25.2 – 40.4
Labor and delivery ward	127	36	28.4	21.0 – 36.7
Post-partum ward	376	87	23.1	19.1 – 27.6
Special care nursery	76	17	22.4	14.1 – 32.7
Labor/delivery/recovery/post-partum ward	364	71	19.5	15.7 – 23.8
Nursery ward	409	12	2.9	1.6 – 4.9
All locations combined[c]	11,282	5635	49.9	49.0 – 50.9

[a] As defined by National Healthcare Safety Network guidance for hospital location mapping in place at the time of the survey.

[b] Locations with ≥50 patients surveyed are shown. The median number of hospitals contributing data from each location was 36 (range 8–122).

[c] Includes locations in the table plus locations with <50 patients that are not shown.

Table 2

Infection sites for which patients received antimicrobial treatment.

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

[a]Antimicrobial drugs could be given for more than one infection site.

Table 3

Five most common antimicrobial drugs given to treat community-onset[a,b] infections and healthcare facility-onset[a,c] infections

Rank	Antimicrobial drugs for community-onset infections, N=5274 No., % of drugs (95% CI)	Antimicrobial drugs for healthcare facility onset infections, N=2220 No., % of drugs (95% CI)
1	Vancomycin[d] 723, 13.7 (12.8–14.7)	Vancomycin[d] 354, 15.9 (14.5–17.5)
2	Ceftriaxone 671, 12.7 (11.8–13.6)	Piperacillin/tazobactam 259, 11.7 (10.4–13.1)
3	Levofloxacin 518, 9.8 (9.0–10.7)	Levofloxacin 170, 7.7 (6.6–8.8)
4	Piperacillin/tazobactam 516, 9.8 (9.0–10.6)	Ceftriaxone 147, 6.6 (5.6–7.7)
5	Azithromycin 342, 6.5 (5.8–7.2)	Metronidazole[d] 101, 4.5 (3.7–5.5)

[a]Table does not include 147 antimicrobial drugs reported to be given for infections with different onset locations (e.g., for community and healthcare facility onset infections) or for infections with unknown onset location.

[b]Antimicrobial drugs are included if they were identified as being given only for community-onset infections, defined as infections for which signs or symptoms began in community settings (e.g., private residences, assisted living facilities, correctional facilities, homeless shelters, halfway houses, substance abuse rehabilitation facilities, etc.).

[c]Antimicrobial drugs are included if they were identified as being given only for healthcare facility-onset infections, defined as infections for which signs or symptoms began in the survey hospital or in another healthcare facility (e.g., another acute care hospital, long term care facility, outpatient dialysis center or infusion center, etc.) prior to transfer to the survey hospital.

[d]Parenteral formulation of the drug.

Table 4

Five most common antimicrobial drugs given to patients receiving antimicrobial drugs to treat infections in critical care and non-critical care locations.

Rank	Patients in critical care locations receiving infection treatment, N=788 No., % of patients (95% CI)	Patients in non-critical care locations receiving infection treatment, N=3490 No., % of patients (95% CI)
1	Vancomycin[a] 275, 34.9 (31.6–38.3)	Vancomycin[a] 828, 23.7 (22.3–25.2)
2	Piperacillin/tazobactam 202, 25.6 (22.7–28.8)	Ceftriaxone 705, 20.2 (18.9–21.6)
3	Levofloxacin 133, 16.9 (14.4–19.6)	Piperacillin/tazobactam 586, 16.8 (15.6–18.1)
4	Ceftriaxone 120, 15.2 (12.9–17.9)	Levofloxacin 561, 16.1 (14.9–17.3)
5[b]	Gentamicin 65, 8.2 (6.5–10.3)	Ciprofloxacin 339, 9.7 (8.8–10.7)

[a]Parenteral formulation.

[b]When neonatal critical care units were excluded, parenteral metronidazole was the 5th most commonly administered antimicrobial drug (8.7% of 691 patients receiving antimicrobial drugs to treat infections in non-neonatal critical care units [95% CI, 6.8%–11.0%]). There was no change in rankings of antimicrobial drugs given to patients receiving infection treatment in non-critical care units when neonatal units were excluded.

Table 5

Five most common antimicrobial drugs for treatment of community onset and healthcare facility-onset infections in non-neonatal critical care and non-critical care locations.

	Antimicrobial drugs for community-onset[a] infections		Antimicrobial drugs for healthcare facility-onset[b] infections	
	Non-neonatal[c] critical care, N=845	Non-neonatal[d] non-critical care, N=4399	Non-neonatal[c] critical care, N=557	Non-neonatal[d] non-critical care, N=1461
Rank	No., % of drugs (95% CI)	No., % of drugs (95% CI)	No., % of drugs (95% CI)	No., % of drugs (95% CI)
1	Vancomycin[e] 141, 16.7 (14.3–19.3)	Vancomycin[e] 582, 13.2 (12.3–14.3)	Vancomycin[e] 102, 18.3 (15.3–21.7)	Vancomycin[e] 222, 15.2 (13.4–17.1)
2	Piperacillin/tazobactam 113, 13.4 (11.2–15.8)	Ceftriaxone 573, 13.0 (12.1–14.0)	Piperacillin/tazobactam 85, 15.3 (12.5–18.4)	Piperacillin/tazobactam 173, 11.8 (10.3–13.6)
3	Ceftriaxone 98, 11.6 (9.6–13.9)	Levofloxacin 426, 9.7 (8.8–10.6)	Levofloxacin 39, 7.0 (5.1–9.4)	Levofloxacin 130, 8.9 (7.5–10.4)
4	Levofloxacin 92, 10.9 (8.9–13.1)	Piperacillin/tazobactam 403, 9.2 (8.3–10.0)	Fluconazole 35, 6.3 (4.5–8.5)	Ceftriaxone 126, 8.6 (7.3–10.2)
5	Azithromycin 50, 5.9 (4.5–7.7)	Azithromycin 291, 6.6 (5.9–7.4)	Metronidazole[e] 25, 4.5 (3.0–6.5)	Metronidazole[e] 72, 4.9 (3.9–6.1)

[a] Antimicrobial drugs are included if they were identified as being given only for community-onset infections, defined as infections for which signs or symptoms began in community settings (e.g., private residences, assisted living facilities, correctional facilities, homeless shelters, halfway houses, substance abuse rehabilitation facilities, etc.).

[b] Antimicrobial drugs are included if they were identified as being given only for healthcare facility-onset infections, defined as infections for which signs or symptoms began in the survey hospital or in another healthcare facility (e.g., another acute care hospital, long term care facility, outpatient dialysis center or infusion center, etc.) prior to transfer to the survey hospital.

[c] Excludes antimicrobial drugs given to patients in level III and level II/III neonatal intensive care units.

[d] Excludes antimicrobial drugs given to patients in neonatal step-down units and well baby nurseries.

[e] Parenteral formulation of the drug.