Appropriateness of Antibiotic Prescribing in U.S. Children's Hospitals: A National Point Prevalence Survey

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Key Points: At US children's hospitals, 35% of children are receiving one or more antibiotics at any given time, and 26% of these children are receiving suboptimal antibiotics. Nearly half of suboptimal antibiotics are not reviewed by antimicrobial stewardship programs.

ABSTRACT

Background: Studies estimate that 30-50% of antibiotics prescribed for hospitalized patients are inappropriate, but pediatric data are limited. Characterization of inappropriate prescribing practices for children are needed to guide pediatric antimicrobial stewardship.

Methods: Cross-sectional analysis of antibiotic prescribing at 32 US children's hospitals. Subjects included hospitalized children with ≥1 antibiotic order at 0800 on one day per calendar quarter, over six quarters (Quarter 3 2016 – Quarter 4 2017). Antimicrobial stewardship program (ASP) physicians and/or pharmacists used a standardized survey to collect data on antibiotic orders and evaluate appropriateness. The primary outcome was the percentage of antibiotics prescribed for infectious use that were classified as suboptimal, defined as inappropriate or needing modification.

Results: Of 34 927 children hospitalized on survey days, 12 213 (35.0%) had ≥1 active antibiotic order. Among 11 784 patients receiving antibiotics for infectious use, 25.9% were prescribed ≥1 suboptimal antibiotic. Of the 17 110 antibiotic orders prescribed for infectious use, 21.0% were considered suboptimal. Most common reasons for inappropriate use were bug-drug mismatch (27.7%), surgical prophylaxis >24 hours (17.7%), overly broad empiric therapy (11.2%), and unnecessary treatment (11.0%). The majority of recommended modifications were to stop (44.7%) or narrow (19.7%) the drug. ASPs would not have routinely reviewed 46.1% of suboptimal orders.

Conclusions: Across 32 children's hospitals, approximately 1 in 3 hospitalized children are receiving one or more antibiotics at any given time. One quarter of these children are receiving suboptimal therapy, and nearly half of suboptimal use is not captured by current ASP practices.

Keywords: appropriate antibiotic use; antibiotic prevalence; hospitalized children; antimicrobial stewardship

INTRODUCTION

Antibiotics are prescribed frequently for children. Among pediatric outpatients, they are the most commonly prescribed drug class [1], and over half of hospitalized United States (US) children receive antibiotics [2,3]. While antibiotics are life-saving medications, their use is not free from adverse effects. Antibiotic use contributes to antibiotic resistance [4,5]; infections with resistant organisms incur substantial morbidity and mortality and are predicted to become a major cause of worldwide mortality [6–8]. Antibiotic use also promotes the development of *C. difficile* infection [9] and is the leading cause of emergency department visits for adverse drug events in children [10]. Judicious antibiotic use is therefore paramount to preventing unintended harm and limiting the development of antibiotic resistance.

To date, evaluation of appropriate pediatric antibiotic prescribing in US populations has been most extensive in outpatient settings [11,12]. While multiple studies in adult inpatient populations have demonstrated that 30% - 50% of antibiotics are prescribed inappropriately [13–15], few studies have focused on US pediatric populations, and these reflect only single centers or specific diagnoses or interventions [16–18]. Outside the US, studies have attempted to quantify inappropriate prescribing in hospitalized children more broadly [19–30]. However, application of these data to US populations is limited by country-specific factors such as regional disease burden and antibiotic resistance patterns, as well as risk tolerance and hierarchical structure that influence antibiotic prescribing [31]. Furthermore, most studies do not include detailed assessments of prescribing appropriateness. Such data are needed to inform antimicrobial stewardship efforts for hospitalized children. To address these gaps, a multicenter study utilizing serial point prevalence surveys was undertaken to comprehensively evaluate antimicrobial utilization and appropriateness in a large sample of US hospitalized children.

METHODS

Study Design and Setting

A serial, cross-sectional analysis of antibiotic prescribing at 32 US children's hospitals was conducted from July 2016 through December 2017. Participating hospitals were recruited from the Sharing Antimicrobial Reports for Pediatric Stewardship (SHARPS) Collaborative [32]. The SHARPS Collaborative includes over 60 freestanding children's hospitals or tertiary children's hospitals within a larger medical system. Each hospital completed up to six single-day surveys of antimicrobial use. Surveys were completed within a specified three-week period during each calendar quarter, with individual hospitals selecting their survey date. Institutional review board (IRB) approval was obtained at Children's Mercy-Kansas City (CMH, the coordinating center) and at hospitals that did not adopt central IRB approval through CMH.

Study Population

Patients 0-17 years of age admitted at 0800 on the day of each quarterly survey with an active order for an enteral, parenteral (intravenous, intramuscular, intrathecal, or intraperitoneal), inhaled, or rectal antimicrobial were included.

Data Collection

Data collection was performed by physician and/or pharmacist members of each hospital's antimicrobial stewardship program (ASP). Data were collected via a standardized data collection form utilized by the Global Antimicrobial Resistance and Prescribing in Neonates and Children (GARPEC) project [25], with the addition of questions developed by the SHARPS Collaborative to assess appropriate prescribing. Data were entered into a centralized REDCap (Research Electronic

Data Capture) [33,34] database hosted at CMH. On survey days, hospitals collected census data and identified patients with active antimicrobial orders via the electronic medical record. Chart review was performed to collect patient-specific clinical and antimicrobial data, including dose, route, indication, and if/when the ASP would routinely review the antimicrobial (Supplemental Material, Appendix A).

For antibiotics, hospitals assessed 1) appropriateness of each order, based on clinical judgment of the ASP physician or pharmacist, and 2) whether the ASP would recommend modification of the order were it reviewed as part of routine ASP activities. For inappropriate antibiotics, hospitals selected from pre-specified reasons for inappropriateness: 1) bug-drug mismatches that require narrowing or broadening therapy based on culture and susceptibility or rapid diagnostics, 2) unnecessary duplicate therapies (e.g. double anti-anaerobic coverage or double gram-negative coverage for non-carbapenemase-resistant Enterobacteriaceae infections), 3) highly bioavailable antibiotics being administered intravenously in a patient currently receiving enteral feeds or medications; 4) surgical prophylaxis >24 hours, and 5) other. “Other” included any additional reasons that antibiotic use was judged to be inappropriate based on routine ASP practices at each site, and if selected, was accompanied by free text explanation. For antibiotics needing modification, hospitals selected from a pre-specified list of 18 reasons for modification (e.g. Stop [without a change to another antibiotic], Narrow empirically, Narrow based on culture and susceptibility [Supplemental Material, Appendix A]), or selected other, with free text explanation. Hospitals could only record one inappropriate reason and one modification per antibiotic and were instructed to record the most important reason and/or modification.

Data Analysis

Data from all surveys were pooled for analysis. After initial description of antimicrobial prevalence, we restricted the analysis to antibiotics prescribed for infectious use (infection treatment or prophylaxis), excluding antibiotics prescribed for non-infectious indications (e.g. gastrointestinal motility). Orders were classified as infectious or non-infectious based on the reported indication. For indications listed as "other," the accompanying free text was used to re-classify the order into an existing indication category or to generate additional categories (Supplemental Material, Appendix B).

The primary outcome was the percentage of antibiotic orders classified as suboptimal, defined as those classified as inappropriate, requiring a modification, or both. Secondary outcomes included the frequencies of individual drug use, indications, inappropriate reasons, recommended modifications, and ASP review status for each antibiotic. A substantial proportion of antibiotics were classified as inappropriate with a reason of "other." Therefore, additional post-hoc inappropriate use categories were created, with re-classification of "other" reasons into these categories (Supplemental Material, Appendix C).

Additional analysis was conducted to assess factors associated with suboptimal antibiotic use. For this analysis, antibiotics were grouped into classes (Supplemental Material, Appendix D). Bivariate analysis was conducted to assess the association of suboptimal antibiotic use with antibiotic class, indications, and patient characteristics. A multilevel, generalized linear model was used to examine how the odds of suboptimal antibiotic use related to prescribing-level (e.g., antibiotic class, indication for treatment) and patient-level (e.g., chronic conditions, medical service type, ventilation status) covariates. Random intercept models were constructed using the participating hospital as a random effect and employing compound symmetry for the covariance matrix. Fit statistics and assessment for confounding were used to identify parsimonious models. All analyses were completed using SAS version 9.4.

RESULTS

Study Population and Antibiotic Prevalence

Thirty-two hospitals contributed one or more quarters of survey data, and 16 hospitals contributed data in all six quarters. Among 34927 patients admitted across all survey days, 13051 (37.4%) had one or more active antimicrobial orders (22196 antimicrobial orders total). Antibiotics were prescribed for 12213 (35.0%) patients, totaling 17844 orders (80.4% of all antimicrobial orders; 68.1% administered parenterally, 30.5% enterally, 1.4% inhaled). Other antimicrobials included antifungals (2822 [12.7%]), antivirals (1374 [6.2%]), and antiparasitics (97 [0.4%]). Infectious use accounted for 17110 (95.9%) antibiotic orders and 11784 (96.5%) patients receiving antibiotics (7475 [63.4%] receiving one antibiotic, 3489 [29.6%] receiving two, and 820 [7.0%] receiving three or more), and all further results referring to antibiotics include only these orders and patients.

Median age among patients receiving antibiotics was 3.8 years (interquartile range: 0.5, 11.0 years, Table 1), and 6452 (55.0%) were male. Half of patients were admitted to medical services, followed by non-neonatal intensive care units (ICUs; 21.4%). Most patients (77.2%) had ≥1 chronic condition, and 34.5% had two or more.

Sulfamethoxazole and trimethoprim (SMX/TMP) was the most commonly prescribed antibiotic, accounting for 1880 (11.0%) orders, followed by ceftriaxone (9.2%), vancomycin (9.1%), and piperacillin/tazobactam (7.0%; Figure 1). The top 10 ordered antibiotics accounted for 68.9% of antibiotic orders and were prescribed primarily (>90%) for treatment, except SMX/TMP and cefazolin (87.3% and 77.2% prescribed for prophylaxis, respectively). Treatment for bacterial lower respiratory tract infection (LRTI) was the most common indication (17.5%), followed by prophylaxis for medical problems (15.9%), probable or proven sepsis (13.9%) and prophylaxis for surgical problems (8.7%; Figure 2).

Suboptimal Antibiotic Use

Analysis of suboptimal use (inappropriate and/or requiring modification) was able to be performed for 16891 (98.7%) antibiotic orders. Of these, 3544 (21.0%) were considered suboptimal, with 2293 (13.6%) classified as inappropriate and 1235 (7.3%) classified as appropriate but needing modification. A recommended modification was recorded for nearly all suboptimal antibiotics (*n*=3458 [97.6%]). Overall, 3027 (25.9%) patients receiving antibiotics were prescribed ≥1 suboptimal antibiotic (inter-hospital range: 7.4% - 46.8%, Figure 3). The percentage of orders judged suboptimal did not differ between hospitals that completed six vs. less than six surveys (20.7% vs. 21.4%, *P*=0.288) or by season (Q1: 21.8%, Q2: 20.1%, Q3: 21.5%, Q4: 20.4%; *P*=0.185).

Among suboptimal antibiotic orders classified as inappropriate, the most frequent reasons for this classification were bug-drug mismatches that required narrowing or broadening of therapy based on culture and susceptibility or rapid diagnostics (*n*=635 [27.7%]) and surgical prophylaxis >24 hours (*n*=407 [17.7%]; Figure 4). Among suboptimal antibiotics with a recommended modification, ASPs recommended stopping 1583 (44.7%) antibiotics without replacement (Figure 5). An additional 698 (19.7%) antibiotics warranted replacement with a narrower-spectrum antibiotic, either empirically or based on culture results. Need for dose modification (changes to dose amount or frequency) accounted for 12.7% of suboptimal antibiotics.

While SMX/TMP was the most frequently ordered antibiotic, only 8.5% of SMX/TMP orders were suboptimal (Figure 1). SMX/TMP medical prophylaxis was rarely judged suboptimal (69/1535 orders [4.5%]), in contrast to 28.8% (88/305) of SMX/TMP prescribed for other reasons. Of the remaining top 10 antibiotics, cefazolin, clindamycin, and vancomycin were most often suboptimal (28.7%, 26.7%, and 25.7%, respectively). However, the drugs most often considered suboptimal (excluding those with ≤5 total orders) were not among the top 10 antibiotics: enteral third-generation cephalosporins (cefpodoxime, cefixime, and cefdinir; 44/90 orders [48.9%]), second-generation cephalosporins without anaerobic activity (cefprozil and cefuroxime; 17/48 [35.4%]) and ciprofloxacin (101/301 [33.6%]).

By indication, the greatest number of suboptimal orders were prescribed for proven or probable bacterial LRTI (*n*=655, 22.0% of bacterial LRTI indications, Figure 2). However, the indications with the greatest percentage of suboptimal orders were surgical prophylaxis, with 588 (39.8%) of 1476 orders classified as suboptimal, along with upper respiratory tract infections (211/631 [33.4%]), viral LRTI (48/64 [75.0%]), urinary tract infections (180/560 [32.1%]), fever of unknown origin (24/69 [34.8%]), and unknown indications (123/270 [45.6%]). Among all suboptimal orders, bacterial LRTI, surgical prophylaxis, and probable or proven sepsis accounted for almost half (18.5%, 16.6%, and 12.9%, respectively).

Suboptimal prescribing also varied by clinical characteristics. Of patients receiving antibiotics, 33.6% (827/2459) in non-neonatal ICUs were prescribed ≥1 suboptimal antibiotic, followed by surgical services (472/1673 [28.2%]), neonatal ICUs (354/1531 [23.1%]), and medical services (1303/5790 [22.5%]). Among those receiving invasive ventilation, 32.9% (718/2180) of patients receiving antibiotics were prescribed suboptimal antibiotics, followed by 25.4% (354/1393) of those receiving non-invasive ventilation and 24.1% (1912/7919) of those receiving no ventilation. Suboptimal prescribing occurred in 24.2% (645/2021) of patients without chronic conditions, 25.4% (1260/3709) of patients with one chronic condition, and 27.7% (1115/4023) of patients with ≥2 chronic conditions.

Factors Associated with Suboptimal Prescribing

On bivariate analysis, suboptimal prescribing was not associated with sex, patient age or documented adverse antibiotic reactions, but was significantly associated with number of chronic conditions, ventilation status and medical service type. However, these patient-level characteristics did not provide meaningful improvement based on the fit statistics of the multilevel regression models, and a more parsimonious model was chosen as the final model. After adjusting for indication and treatment documentation, several antibiotic classes were significantly associated with suboptimal prescribing, compared with narrow-spectrum penicillins (Table 2). Oral third-generation cephalosporins, carbapenems, fluoroquinolones, broad-spectrum gram-positive agents (e.g. linezolid, daptomycin), and vancomycin had the highest odds of suboptimal prescribing. Among treatment indications, the odds of suboptimal prescribing were significantly higher for several indications compared to medical prophylaxis, including viral LRTI, unknown indications, and surgical prophylaxis.

Antimicrobial Stewardship Review

ASPs would not have reviewed 1626 (46.1%) suboptimal antibiotics through routine ASP activities. Among antibiotics routinely reviewed by ASPs, the percentage of suboptimal orders decreased following routine ASP review: 24.8% (873/3519) among antibiotics awaiting routine review, 19.7% (837/4245) among antibiotics reviewed in the past 5 days, and 12.9% (192/1483) among antibiotics reviewed >5 days ago (*P*=<0.001). Among antibiotics not routinely reviewed by ASPs, 21.4% (1626/7602) were suboptimal; of these, cefazolin, clindamycin, and ceftriaxone were most common (11.4%, 9.9%, and 9.7% of suboptimal, unreviewed antibiotics, respectively).

DISCUSSION

In this multicenter study of nearly 35000 hospitalized children, 35% were receiving one or more antibiotics on survey days. Of those receiving antibiotics for infectious use, 26% were prescribed at least one suboptimal antibiotic. Additionally, 46% of suboptimal antibiotic orders would not have been reviewed by ASPs as part of their routine daily work. These data underscore the need for robust programs to support optimal antibiotic use for hospitalized children.

Previous studies of antibiotic use in US children's hospitals indicate that approximately 60% of children receive an antibiotic at some time during their stay [2,3]. Our calculation of antibiotic prevalence is not directly comparable because we measured active orders on a single day and instead provides an additional metric to describe antibiotic use in hospitalized children. This prevalence is similar to the 2012 worldwide ARPEC point prevalence survey, in which 37% of pediatric inpatients received antimicrobials on survey days, of which 86% were antibiotics [29].

We found a lower rate of suboptimal prescribing than has been reported in US adult populations (30-50%) [13–15]. Our rate was also lower than that of a small study in Turkish children (34%) [23], but higher than the rate reported among 631 hospitalized children in Australia (18%) [30] and 336 children in Sweden (<10% when guidelines available) [28]. Most suboptimal use in our study was related to over-prescribing: ASPs would have recommended stopping nearly half of suboptimal antibiotics, and another 20% warranted replacement with a narrower-spectrum antibiotic. There was also considerable variability in the degree of suboptimal prescribing, with up to 47% of patients receiving suboptimal antibiotics at some hospitals. This variability warrants further investigation and may identify opportunities for hospitals to improve ASP efforts and prescribing. Importantly, many hospitals in this study have well-established ASPs, so these results may underestimate the rate of suboptimal prescribing at hospitals with newer ASPs or those without pediatric ASPs.

This study highlights areas in which ASPs can focus efforts to further optimize antibiotic use. Bacterial LRTI was the most common indication for antibiotic use, consistent with previous studies in US and global pediatric populations [3,25,29], and accounted for the largest share of suboptimal orders (18%), making it a prime target for additional ASP intervention. Surgical prophylaxis, most commonly prolonged duration, also accounted for a substantial portion of suboptimal orders (17%) and is likely another area in which ASPs should focus additional efforts. Notably, the recently revised

CDC guidelines for prevention of surgical site infection recommend limiting antibiotic prophylaxis for clean and clean-contaminated procedures to a single pre-operative dose [35]. Thus, an even greater proportion of surgical prophylaxis in our study would likely now be considered suboptimal, as our pre-specified criterion for inappropriate surgical prophylaxis allowed up to 24 hours of prophylaxis.

Our study also examined suboptimal use by drug class, a common framework through which ASPs structure their reviews. After adjusting for indication and treatment documentation, drug classes with the highest odds of being considered suboptimal included oral third general cephalosporins, broad-spectrum gram-positive agents, carbapenems, clindamycin, metronidazole, fluoroquinolones, and vancomycin. Many ASPs review only certain antibiotics; such ASPs should consider evaluating these and other drug classes associated with higher odds of suboptimal prescribing if they are not reviewed routinely.

Arguably the most important finding of our study is that nearly half of suboptimal orders would not have been routinely reviewed by ASPs. Additionally, the rate of suboptimal use among antibiotics that ASPs would not routinely review (21%) was only slightly lower than that of orders that the ASP would be reviewing soon (25%). These data demonstrate that antibiotics not currently targeted for routine review still have significant need for ASP oversight. While extension of routine review to all antibiotics is an obvious solution, this is resource-intensive and may not be feasible at all hospitals. ASPs may need to consider alternative strategies to address additional suboptimal use, such as guideline development, use of order sets, or required order end dates. ASPs also need to develop strategies to identify additional areas of suboptimal use, such as periodic review of all antibiotics for appropriateness. Encouragingly, rates of suboptimal prescribing among routinely reviewed antibiotics were lower among orders that had already undergone routine ASP review by the survey day, compared to those yet to be reviewed. This suggests that ASP recommendations are impactful, consistent with prior pediatric studies [36,37].

This study has several strengths due to its multicenter design, detailed data collection, capture of data in all seasons, and systematic assessment of antibiotic appropriateness, but limitations exist. First, data collection was limited to six single-day surveys per institution. Second, we lacked a standard definition for "inappropriateness" which may have led to inconsistent assessment of this outcome. This was partially mitigated by providing an operations manual to all sites with guidance on survey completion and by discussion on monthly webinars hosted by the SHARPS Collaborative. Additionally, the composite outcome of suboptimal use captured all antibiotics on which ASPs would act, regardless of inappropriate classification. Furthermore, a recommended modification was recorded for 98% of suboptimal orders, enabling a thorough understanding of ASP assessment of these orders. Characterization of inappropriate use was also limited by the need for post-hoc analysis of free text comments in almost 40% of orders classified as inappropriate. Finally, not all centers participated in each survey, which may have biased our results towards centers that participated more consistently. Patient volume also varied by institution, so larger hospitals may have disproportionately influenced the prevalence of suboptimal use.

In summary, antibiotic use is common among hospitalized US children, and high rates of suboptimal use persist, despite ASP efforts. While current ASP review practices capture many suboptimal antibiotic orders, a substantial proportion remain unaddressed. This study highlights the need for ASPs to look beyond current practices to identify and intervene upon additional suboptimal use and denotes areas in which to potentially expand efforts. Such evolution is imperative to ensure optimal antibiotic use for all hospitalized children.

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CONFLICTS OF INTEREST

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Table 1. Demographic and Clinical Characteristics of Hospitalized Children Receiving Antibiotics

	Patients (N=11,784)
Patient Age (years)	3.83 [0.52, 10.96]
Gender	
Male	6452 (55.0%)
Female	5273 (45.0%)
Medical Service Type	
Medical	5846 (50.6%)
Surgical	1693 (14.6%)
Neonatal Intensive Care	1537 (13.3%)
Non-neonatal Intensive Care	2477 (21.4%)
Ventilation Status	
Invasive Ventilation	2189 (18.7%)
Non-Invasive Ventilation	1408 (12.0%)
No Ventilation	7990 (68.3%)
Don't Know	117 (1.0%)
Chronic Conditions	

0	2684 (22.8%)
1	5014 (42.6%)
2	2627 (22.3%)
3 or more	1433 (12.2%)
Documented History of Adverse Antibiotic Reaction	
No	10034 (85.3%)
Yes	1733 (14.7%)
Calendar Quarter of Survey	
2016-Q3	2136 (18.1%)
2016-Q4	2324 (19.7%)
2017-Q1	2205 (18.7%)
2017-Q2	1965 (16.7%)
2017-Q3	1798 (15.3%)
2017-Q4	1356 (11.5%)

Includes children (0-17 years of age) with an order for ≥1 antibiotic (prescribed for infectious indications, via enteral, parenteral, inhaled, or rectal routes) at 0800 on quarterly survey days. Results are presented as median [interquartile range] or *N* (%) as appropriate.

Table 2: Adjusted Odds of Suboptimal Antibiotic Use Among Hospitalized Children

Factor	*Odds Ratio*	*P-value*	*95% CI*
Indication for Antibiotic Use			
Prophylaxis for medical problems	*-ref-*	---	---
Cardiac infections	0.66	0.171	0.36, 1.20
Febrile neutropenia/fever	0.79	0.079	0.61, 1.03
Gastrointestinal tract infections	1.12	0.324	0.89, 1.41
Joint/bone infections	1.00	0.999	0.70, 1.42
Miscellaneous	0.77	0.301	0.46, 1.27
Probable/proven central nervous system infections	0.90	0.490	0.67, 1.21
Probable/proven catheter-related bloodstream infection	1.36	0.021	1.05, 1.75
Probable/proven sepsis; rule-out serious bacterial infection in infant	1.48	0.001	1.21, 1.81
Prophylaxis for surgical problems	4.39	<.0001	3.51, 5.49
Probable/proven bacterial lower respiratory tract infection	1.68	<.0001	1.39, 2.03
Probable/proven viral lower respiratory tract infection	18.52	<.0001	10.06, 34.07
Pyrexia of unknown origin	2.47	0.001	1.43, 4.29

Skin/soft tissue infections	1.43	0.005	1.11, 1.82
Treatment for surgical disease	0.97	0.806	0.73, 1.27
Unknown	4.82	<.0001	3.58, 6.49
Upper respiratory infections	2.97	<.0001	2.34, 3.78
Urinary tract infections	2.70	<.0001	2.11, 3.46
Antibiotic Class			
Narrow-spectrum penicillin	*-ref-*	---	---
1st generation cephalosporin	1.05	0.644	0.85, 1.31
2nd generation cephalosporin	1.32	0.166	0.89, 1.96
Enteral 3rd generation cephalosporin	3.70	<.0001	2.34, 5.85
Parenteral 3rd generation cephalosporin	1.71	<.0001	1.43, 2.04
Aminoglycoside	1.15	0.184	0.94, 1.41
Aminopenicillin and beta-lactamase inhibitor	1.52	0.001	1.20, 1.92
Antipseudomonal beta-lactam	1.52	<.0001	1.28, 1.80
Broad-spectrum gram-positive agent	2.49	<.0001	1.64, 3.77
Carbapenem	2.89	<.0001	2.29, 3.64
Clindamycin	1.92	<.0001	1.55, 2.38

Fluoroquinolone	2.52	<.0001	1.99, 3.19
Macrolide	1.30	0.085	0.96, 1.75
Metronidazole	1.87	<.0001	1.46, 2.39
Miscellaneous	1.09	0.578	0.80, 1.50
Sulfamethoxazole and trimethoprim	0.63	<.0001	0.50, 0.79
Vancomycin	2.07	<.0001	1.73, 2.49
Indication for Antibiotic Use not Documented in Notes	1.49	<.0001	1.30, 1.70

See Supplemental Material, Appendices B (Indications) and D (Antibiotic Classes) for explanations of these classifications.

Figure 1: Most Commonly Prescribed Antibiotics and Percentage Suboptimal

Top 10 most frequently ordered antibiotics for children hospitalized on six quarterly survey days (Q3 2016 – Q4 2017). Antibiotics were classified as suboptimal (inappropriate and/or needing modification) by hospital antimicrobial stewardship programs.

Figure 2: Most Common Indications for Antibiotic Use and Percentage Suboptimal

Top 10 most common indications for antibiotics ordered for children hospitalized on six quarterly survey days (Q3 2016 – Q4 2017). Antibiotics were classified as suboptimal (inappropriate and/or needing modification) by hospital antimicrobial stewardship programs. Abbreviations: LRTI (lower respiratory tract infection), R/O SBI (rule out serious bacterial infection), CRBSI (catheter-related bloodstream infection).

Figure 3. Suboptimal Antibiotic Use Across Hospitals

Percentage of patients receiving antibiotics who were prescribed ≥1 suboptimal antibiotic. Each bar represents one hospital.

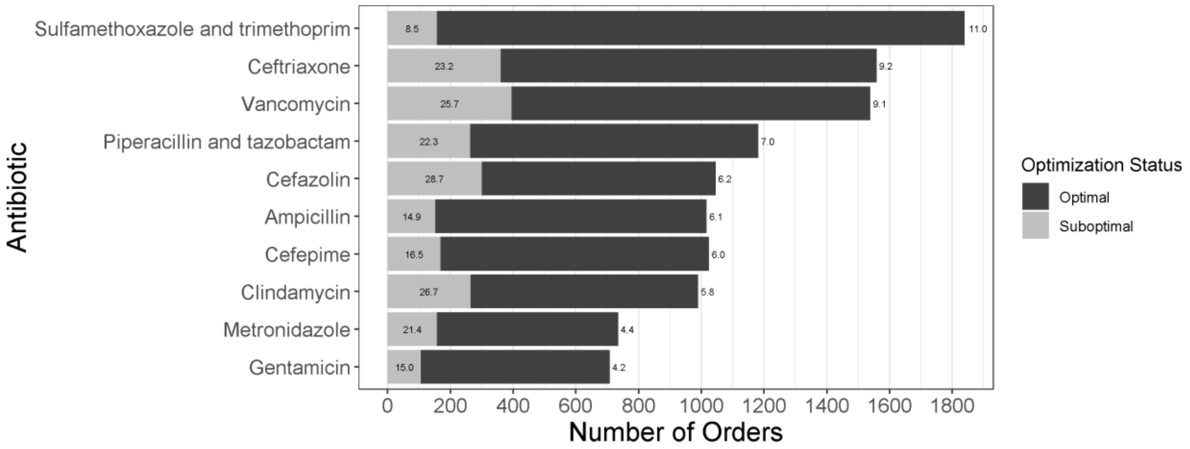
Figure 4. Reasons for Classifying Antibiotic Use as Inappropriate

Antimicrobial stewardship programs classified 2 293 (13.5%) of 16 960 antibiotics ordered for children hospitalized on survey days as inappropriate. See Supplemental Material, Appendices A (pre-specified reasons on survey) and C (post-hoc reason categories) for further explanation of inappropriate reasons.

Figure 5. Recommended Modifications for Suboptimal Antibiotic Orders

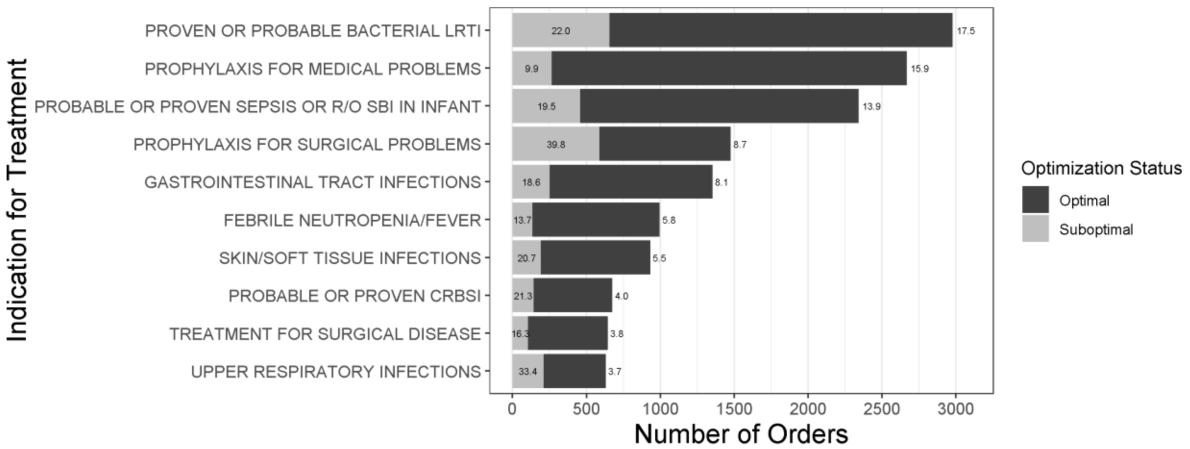
Antibiotics were classified as suboptimal (inappropriate and/or needing modification) by hospital antimicrobial stewardship programs. Of 16 891 antibiotics with this composite outcome assessed, 3 544 (21.0%) were considered suboptimal, and a recommended modification was recorded for 3 458 (97.6%).

Figure 1



Number within each bar indicates percent suboptimal while number to right of each bar indicates the overall percentage of orders

Figure 2



Number within each bar indicates percent suboptimal while number to right of each bar indicates the overall percentage of orders

Figure 3

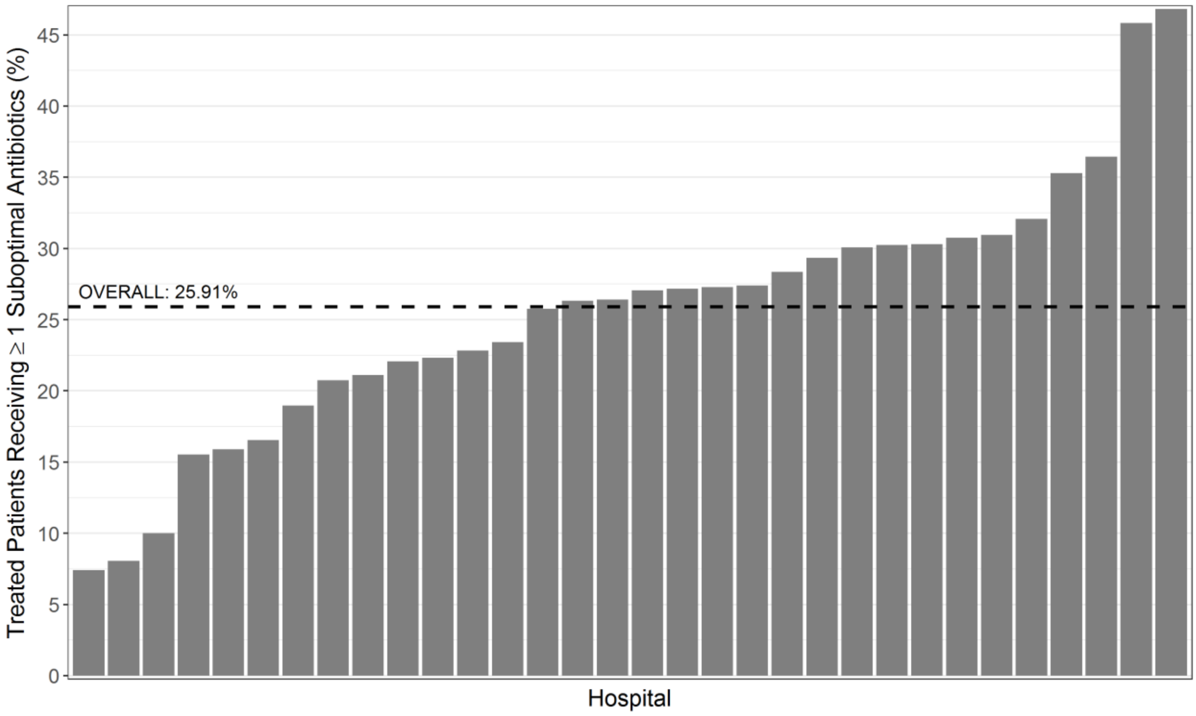
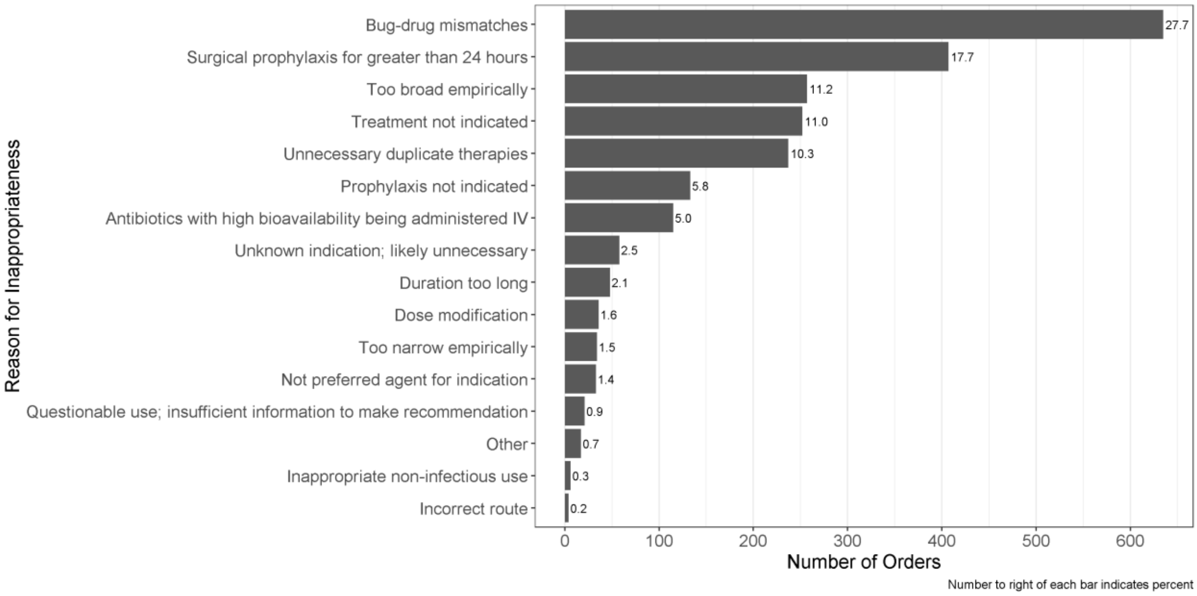
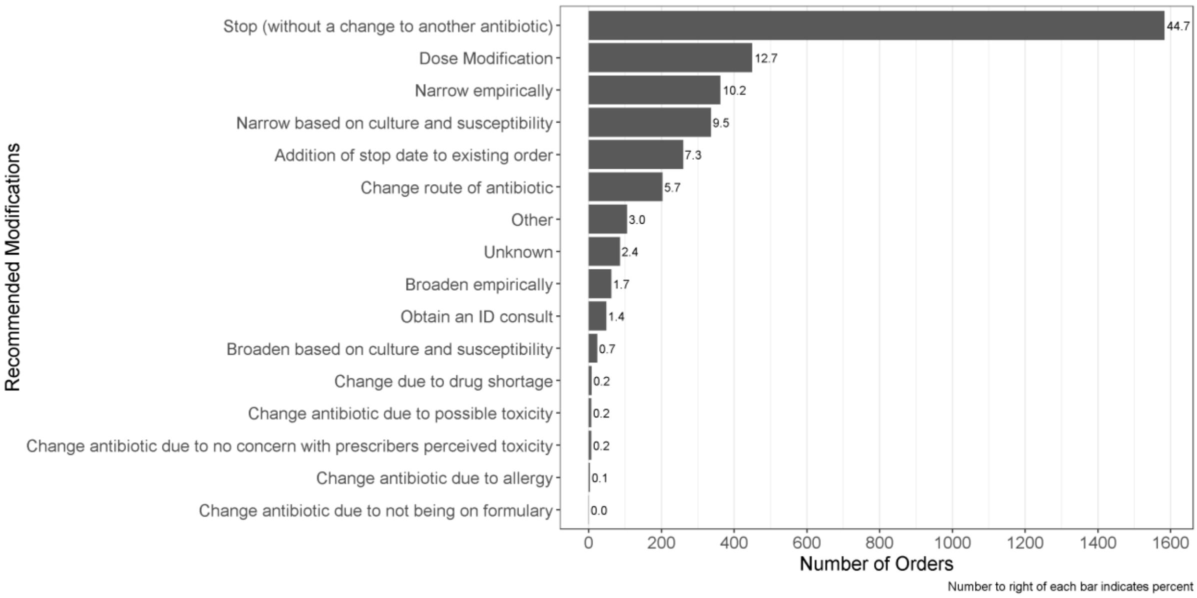

Treated Patients Receiving ≥ 1 Suboptimal Antibiotics (%)
OVERALL: 25.91%
0
5
10
15
20
25
30
35
40
45
Hospital

Figure 4



Reason for Inappropriateness
Bug-drug mismatches
Surgical prophylaxis for greater than 24 hours
Too broad empirically
Treatment not indicated
Unnecessary duplicate therapies
Prophylaxis not indicated
Antibiotics with high bioavailability being administered IV
Unknown indication; likely unnecessary
Duration too long
Dose modification
Too narrow empirically
Not preferred agent for indication
Questionable use; insufficient information to make recommendation
Other
Inappropriate non-infectious use
Incorrect route
27.7
17.7
11.2
11.0
10.3
5.8
5.0
2.5
2.1
1.6
1.5
1.4
0.9
0.7
0.3
0.2
0
100
200
300
400
500
600
Number of Orders
Number to right of each bar indicates percent

Figure 5


Recommended Modifications
Stop (without a change to another antibiotic)
Dose Modification
Narrow empirically
Narrow based on culture and susceptibility
Addition of stop date to existing order
Change route of antibiotic
Other
Unknown
Broaden empirically
Obtain an ID consult
Broaden based on culture and susceptibility
Change due to drug shortage
Change antibiotic due to possible toxicity
Change antibiotic due to no concern with prescribers perceived toxicity
Change antibiotic due to allergy
Change antibiotic due to not being on formulary
44.7
12.7
10.2
9.5
7.3
5.7
3.0
2.4
1.7
1.4
0.7
0.2
0.2
0.2
0.1
0.0
0
200
400
600
800
1000
1200
1400
1600
Number of Orders
Number to right of each bar indicates percent