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Original Article

Benchmarking antimicrobial use to antimicrobial resistance: a comparative study of two hospitals using current National Healthcare Safety Network (NHSN) metrics

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Abstract

Objective: We aimed to determine whether benchmarking antimicrobial use (AU) to antimicrobial resistance (AR) using select AU/AR ratios is more informative than AU metrics in isolation.

Design: We retrospectively measured AU (antimicrobial therapy days per 1,000 days present) and AU/AR ratios (specific antimicrobial therapy days per corresponding AR event) in two hospitals during 2020 through 2022. We then had antimicrobial stewardship committee members evaluate each AU and corresponding AU/AR value and indicate whether they believed it represented potential overuse, appropriate use, or potential underuse of the antimicrobials, or whether they could not provide an assessment.

Setting: Two acute-care hospitals.

Patients: Hospitalized patients.

Results: In semi-annual facility-wide analyses, echinocandins had a median AU/AR ratio of 658.5 therapy days per fluconazole-resistant *Candida* event in Hospital A, IV vancomycin had a median AU/AR ratio of 114.9 and 108.2 therapy days per methicillin-resistant *Staphylococcus aureus* event in Hospital A and B, respectively, and linezolid had a median AU/AR ratio of 33.8 and 88.0 therapy days per vancomycin-resistant *Enterococcus* event in Hospital A and B, respectively. When AU and AU/AR values were evaluated by stewardship committees, more respondents were able to assess antimicrobial use based on AU/AR values compared to AU values. Based on AU/AR ratios, most respondents identified potential overuse of echinocandins and IV vancomycin in Hospital A, and potential overuse of linezolid and IV vancomycin in Hospital B.

Conclusion: Select AU/AR ratios provided informative metrics to antimicrobial stewardship personnel, which can be used to motivate audits of antimicrobial administration to determine appropriateness.

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Introduction

US hospitals have high rates of antimicrobial use (AU).[1] While antimicrobials are lifesaving when used appropriately, any use can result in adverse effects and increased antimicrobial resistance (AR).[2] To aid antimicrobial stewardship programs in monitoring AU and AR trends,[3] the National Healthcare Safety Network (NHSN) has developed AU and AR modules to provide metrics for analyzing and reporting inpatient data.[4]

The primary metric in the AU module is antimicrobial days per 1,000 days present. Antimicrobial days for specific administered agents are summed in aggregate, as are number of patient days by care location or facility. To benchmark across institutions, NHSN promotes use of Standardized Antimicrobial Administration Ratio (SAAR) metrics, which are calculated by dividing observed by predicted AU stratified by antimicrobial category, location, and population.[5] While conceptually sound and valuable, SAAR metrics are limited by suboptimal risk adjustment given inputs that consist primarily of facility-level characteristics such as hospital teaching status and number of hospital and ICU beds.[6–8]

Since AU for several antimicrobials should be guided by local AR rates, benchmarking select AU to AR may provide complementary and more actionable metrics. NHSN reports a frequency table showing the number of AR events meeting specific AR phenotypes. Select AU can be benchmarked against these AR events in what we have proposed as AU/AR ratios,[9] wherein antimicrobials are paired with corresponding AR events if they are typically active against the AR organism and frequently used to

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treat it in clinical practice. In this study, we retrospectively measured AU and AU/AR ratios facility-wide and in select ICUs in two hospitals during 2020 through 2022, and determined whether antimicrobial stewardship committee members were more frequently able to provide an assessment of antimicrobial use with AU/AR ratios compared to AU metrics in isolation.

Methods

Study settings and data sources

Hospital A is a 671-bed university hospital, whereas Hospital B is a 186-bed community hospital. Both hospitals are part of Rush University System for Health (RUSH) and share an electronic health record (Epic; Verona, Wisconsin). Hospital A has neuroscience, orthopedic, solid-organ transplant, and cancer centers, whereas Hospital B refers to Hospital A for these specialized services. We evaluated facility-wide AU and AR metrics at both hospitals, and AU and AR metrics at the medical ICU of Hospital A and the sole ICU of Hospital B. To minimize the burden on antimicrobial stewardship committee members during the evaluation phase, we limited analyses to facility-wide metrics at both hospitals and one ICU at each hospital. Ward data were represented in facility-wide metrics, and the medical ICU of Hospital A was most similar to the sole ICU of Hospital B in terms of patient population. Monthly AU and AR information were generated using the antimicrobial stewardship module of the electronic health record, AR information was validated by an antimicrobial stewardship pharmacist, and AU and AR information were submitted to NHSN by respective infection control departments. Monthly facility-wide and location-specific AU metrics for 91 antimicrobials, and monthly facility-wide and location-specific AR events for extended-spectrum cephalosporin-resistant *Escherichia coli* and *Klebsiella pneumoniae/oxytoca* (ESCR), carbapenem-resistant Enterobacterales (CRE), multidrug-resistant *Pseudomonas aeruginosa* (MDRPA), methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococcus faecalis* and *E. faecium* (VRE), and fluconazole-resistant *Candida* (FRC), during 2020 through 2022 were extracted from the NHSN portal. AU metrics were expressed as therapy days per 1,000 days present, and AR metrics were expressed as events per 1,000 days present.[4] The study protocol was approved by the RUSH University Institutional Review Board.

Development, computation, and comparison of AU/AR ratios

We convened infectious disease physicians and pharmacists to identify clinically relevant pairs of antimicrobial agents and AR events to compute AU/AR ratios wherein we paired individual antimicrobials or antimicrobial classes with corresponding AR events if they are typically active against the AR organism and frequently used to treat it in clinical practice. We focused on clinically relevant pairings to increase insights from the metrics on individual antimicrobials or antimicrobial classes. Six AU/AR ratios were identified: carbapenems (imipenem, meropenem, ertapenem)/ESCR,[10] daptomycin/VRE,[11] echinocandins (anidulafungin, caspofungin, micafungin)/FRC,[12] linezolid/VRE,[13] new beta-lactam beta-lactamase combination antibiotics (ceftazidime-avibactam, meropenem-vaborbactam, ceftolozane-tazobactam)/MDRPA plus CRE,[14–16] and intravenous (IV) vancomycin/MRSA.[17] For groupings with more than one antimicrobial agent, AU for each agent was summed to establish total exposure. Facility-wide AU/AR ratios were computed by dividing the semi-annual (ie January 1 through June 30, July 1 through December 31) number of antimicrobial therapy days by the corresponding semi-annual number of AR events. Given the paucity of AR events at the location level, AU/AR ratios for the medical ICU at Hospital A and the ICU in Hospital B were computed for 2020 through 2022 in aggregate. We compared metrics for AU and AU/AR ratios, between Hospital A and B, using Wilcoxon signed-rank tests for paired samples; ie semi-annual facility-wide metrics for Hospitals A and B were paired.

Antimicrobial stewardship programs

Distinct antimicrobial stewardship programs exist at Hospitals A and B. Activities at Hospital A include restricted authorization for carbapenems, echinocandins, daptomycin, linezolid, and new beta-lactam beta-lactamase combination antibiotics. In contrast, Hospital B only restricts new beta-lactam beta-lactamase combination antibiotics of antimicrobials examined in this study. Restricted antimicrobials in Hospital A require approval from a pharmacist on call. In addition, new beta-lactam beta-lactamase combination antibiotics in Hospital A require that an infectious diseases physician request for the antimicrobial from a pharmacist on call. For Hospital B, new beta-lactam beta-lactamase combination antibiotics require that an infectious diseases physician request for the antimicrobial. IV vancomycin was not restricted at either hospital.

Evaluation of AU and AU/AR ratios

AU metrics and AU/AR ratios were presented at antimicrobial stewardship committee meetings at Hospital A and B. Committee members were asked to evaluate each AU and AU/AR value for both hospitals and indicate whether they believe it represents potential overuse, appropriate use, or potential underuse of the antimicrobials, or whether they could not provide an assessment. Minimal guidance was given on how to interpret AU and AU/AR metrics. We merely introduced the NHSN AU and AR modules, described limitations of the SAAR, and defined our rationale for benchmarking select AU to AR. To determine whether committee members were more frequently able to provide assessments on antimicrobial use with AU/AR ratios compared to AU metrics, we constructed conditional logistic regression models to account for clustering of responses by committee members. Separate models were constructed to determine whether committee members were more frequently able to identify potential antimicrobial overuse with AU/AR ratios compared to AU metrics. Pairs of AU and AU/AR ratios for which AU/AR ratios were not computable, ie when AR events equaled zero, were excluded from analyses. Analyses were performed in SAS version 9.4 (Cary, North Carolina).

Results

Facility-wide and ICU AU, AR, and AU/AR ratios are in Tables 1-2, trends for facility-wide AU and AU/AR ratios are in Figure 1, and AU and AU/AR assessments in graphical form are in Figure 2, and Supplemental Figures 1–4.

Comparative facility-wide AU and AU/AR metrics

Of antimicrobials examined, IV vancomycin was most frequently used in Hospitals A and B (Table 1, Figure 1). The next most frequently used antimicrobials were echinocandins and carbapenems in Hospital A, and carbapenems and linezolid in Hospital B. AU was statistically significantly greater for IV vancomycin,

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Table 1. Semi-annual **facility-wide** antimicrobial use (AU), antimicrobial resistance (AR) events, and AU/AR ratios from January 1, 2020 through December 31, 2022, in Hospital A and Hospital B*

		Hospital A		Hospital B		
		Median	Range	Median	Range	p-value
AU†	Vancomycin (IV)	49.2	43.5 – 56.1	60.1	53.9 – 70.8	≤0.05
	Carbapenems (imipenem, meropenem, ertapenem)	11.2	10.3 – 14.0	28.0	18.7 – 39.9	≤0.05
	Echinocandins (anidulafungin, caspofungin, micafungin)	12.2	10.2 – 14.0	2.2	1.2 – 3.9	≤0.05
	Linezolid	2.7	2.4 – 3.0	6.9	5.1 – 11.6	≤0.05
	Daptomycin	1.9	1.4 – 3.1	2.1	1.2 – 3.6	NS
	New beta-lactam/beta-lactamase combination antibiotics (ceftazidime-avibactam, meropenem-vaborbactam, ceftolozane-tazobactam)	0.6	0.4 – 1.1	0.2	0 – 3.0	NS
AR‡	ESCR *Escherichia coli* and *Klebsiella pneumoniae/oxytoca*	1.4	1.2 – 1.6	2.4	1.7 – 3.4	≤0.05
	Methicillin-resistant *Staphylococcus aureus*	0.4	0.4 – 0.5	0.6	0.3 – 1.0	NS
	Multidrug-resistant *Pseudomonas aeruginosa* plus carbapenem-resistant Enterobacterales	0.4	0.3 – 0.5	0.4	0.2 – 0.5	NS
	Vancomycin-resistant *Enterococcus*	0.1	0.0 – 0.2	0.0	0 – 0.1	NS
	Fluconazole-resistant *Candida*	0.0	0 – 0.0	0	0 – 0	NS
AU/AR§	Echinocandins → fluconazole-resistant *Candida*	658.5	411.3 – 1,267.0	NA		NA
	Vancomycin (IV) → methicillin-resistant *Staphylococcus aureus*	114.9	102.7 – 129.9	108.2	63.6 – 199.2	NS
	Linezolid → vancomycin-resistant *Enterococcus*	33.8	13.1 – 71.2	88.0	69.0 – 166.0	NS
	Daptomycin → vancomycin-resistant *Enterococcus*	20.7	14.2 – 42.2	28.0	26.0 – 51.0	NS
	Carbapenems → ESCR *Escherichia coli* and *Klebsiella pneumoniae/oxytoca*	8.4	7.7 – 9.1	11.5	9.0 – 15.2	≤0.05
	New beta-lactam/beta-lactamase combination antibiotics → multidrug-resistant *Pseudomonas aeruginosa* plus carbapenem-resistant Enterobacterales	1.5	1.1 – 2.5	0.5	0.0 – 5.8	NS

AU, antimicrobial use; AR, antimicrobial resistance; IV, intravenous; NS, not significant; NA, not applicable because there were no AR events to serve as a denominator for an AU/AR ratio.
* Values are rounded to one decimal place; 0.0 indicates that the value is <0.05 but not zero; 0 indicates zero.
†Antimicrobial therapy days per 1,000 days present.
‡Antimicrobial resistance events per 1,000 days present.
§Antimicrobial therapy days per antimicrobial resistance event.

carbapenems, and linezolid in Hospital B compared to Hospital A, whereas AU was statistically significantly greater for echinocandins in Hospital A compared to Hospital B.

Of AU/AR ratios examined, echinocandins/FRC had the highest values in Hospital A, whereas IV vancomycin/MRSA had the highest values in Hospital B (Table 1, Figure 1). The next highest AU/AR ratios were for IV vancomycin/MRSA and linezolid/VRE in Hospital A, and linezolid/VRE and daptomycin/VRE in Hospital B. The carbapenem/ESCR AU/AR ratio was statistically significantly greater in Hospital B compared to Hospital A.

Comparative ICU AU and AU/AR metrics

Of antimicrobials examined in ICU settings, IV vancomycin was most frequently used in Hospitals A and B (Table 2). The next most frequently used antimicrobials were carbapenems and echinocandins in Hospital A, and carbapenems and linezolid in Hospital B.

Of AU/AR ratios examined in ICU settings, echinocandins/FRC had the highest value in Hospital A, whereas IV vancomycin/MRSA had the highest value in Hospital B (Table 2). The next highest AU/AR ratios were for IV vancomycin/MRSA and carbapenems/ESCR in Hospital A, and carbapenems/ESCR in Hospital B.

Evaluation of AU and AU/AR metrics by antimicrobial stewardship committees

Eighteen antimicrobial stewardship committee respondents assessed AU and AU/AR values from Hospital A and B; sixteen from Hospital A and two from Hospital B. Twenty-four members were present at the antimicrobial stewardship committee meeting in Hospital A, and five members were present at the meeting in Hospital B. The survey response rate was 62%.

When excluding AU and AU/AR pairs where AU/AR values could not be computed given zero AR values, AU/AR metrics were significantly more likely to be evaluable compared to AU values for all comparisons (Figure 2). Evaluability of AU/AR values was always numerically greater than evaluability of corresponding AU values when AU/AR values were computable (Supplemental Figures 1–4).

Potential overuse was identified in significantly more AU/AR values compared to AU values facility-wide for Hospital A and B, and the medical ICU of Hospital A (Figure 2). Based on AU/AR ratios, the majority of respondents interpreted the values as representing potential overuse of echinocandins and IV vancomycin in Hospital A facility-wide; potential overuse of linezolid and IV vancomycin in Hospital B facility-wide; potential overuse of carbapenems, echinocandins, and IV vancomycin in the medical ICU of Hospital A; and potential overuse of carbapenems and IV vancomycin in the ICU of Hospital B (Supplemental Figures 1–4).

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Table 2. Aggregated antimicrobial use (AU), antimicrobial resistance (AR) events, and AU/AR ratios from January 1, 2020 through December 31, 2022, in the **medical ICU** of Hospital A and the **ICU** of Hospital B*

		Hospital A Value	Hospital B Value
AU†	Vancomycin (IV)	120.8	100.1
	Carbapenems (imipenem, meropenem, ertapenem)	39.3	40.8
	Echinocandins (anidulafungin, caspofungin, micafungin)	23.4	6.1
	Linezolid	6.1	9.8
	Daptomycin	4.6	1.5
	New beta-lactam/beta-lactamase combination antibiotics (ceftazidime-avibactam, meropenem-vaborbactam, ceftolozane-tazobactam)	1.5	0.6
AR‡	ESCR *Escherichia coli* and *Klebsiella pneumoniae/oxytoca*	1.8	1.0
	Methicillin-resistant *Staphylococcus aureus*	1.6	0.9
	Multidrug-resistant *Pseudomonas aeruginosa* plus carbapenem-resistant Enterobacterales	1.3	0.6
	Vancomycin-resistant *Enterococcus*	0.4	0
	Fluconazole-resistant *Candida*	0.0	0
AU/AR§	Echinocandins → fluconazole-resistant *Candida*	772.0	NA
	Vancomycin (IV) → methicillin-resistant *Staphylococcus aureus*	73.9	110.5
	Carbapenems → ESCR *Escherichia coli* and *Klebsiella pneumoniae/oxytoca*	21.6	41.0
	Linezolid → vancomycin-resistant *Enterococcus*	14.4	NA
	Daptomycin → vancomycin-resistant *Enterococcus*	10.9	NA
	New beta-lactam/beta-lactamase combination antibiotics → multidrug-resistant *Pseudomonas aeruginosa* plus carbapenem-resistant Enterobacterales	1.2	1.0

AU, antimicrobial use; AR, antimicrobial resistance; IV, intravenous; NA, not applicable because there were no AR events to serve as a denominator for an AU/AR ratio.
* Values are rounded to one decimal place; 0.0 indicates that the value is <0.05 but not zero; 0 indicates zero.
†Antimicrobial therapy days per 1,000 days present.
‡Antimicrobial resistance events per 1,000 days present.
§Antimicrobial therapy days per antimicrobial resistance event.

Discussion

We retrospectively measured AU and AU/AR ratios facility-wide and in select ICUs in two hospitals from 2020 through 2022 and compared AU and AU/AR values between hospitals. We found that accounting for the number of AR events reduced the number of statistically significant differences between hospitals. However, when members of antimicrobial stewardship committees assessed AU and AU/AR values, more respondents were able to assess antimicrobial use and identify potential antimicrobial overuse based on AU/AR values than AU values alone. This suggests that benchmarking select AU to AR events provides potentially actionable metrics that stewardship programs can use to prompt audits of antimicrobial administration to determine appropriateness.

We found most strikingly that echinocandins were very frequently used relative to FRC AR events in Hospital A. This contrast led the AU/AR ratio for this pair to be very high, leading most antimicrobial stewardship committee members to indicate potential overuse. This should prompt a review of indications for echinocandin use, and chart audits to determine appropriateness of use. Indications for echinocandin use include treatment of candidemia,[18] chronic disseminated candidiasis,[19] *Candida* peritonitis,[20] esophageal candidiasis,[21] *Candida* osteoarticular infections,[22] invasive aspergillosis as salvage therapy,[23] and prophylaxis against invasive fungal infections in hematopoietic cell transplant recipients.[24] Notably, suspected infections from *Candida* and *Aspergillus* may not be microbiologically confirmed with culture due to inability to sample infected sites or inadequate sensitivity of microbiological cultures in identifying the organism. Moreover, cultures may not always be indicated, as in the case of esophageal candidiasis where the diagnosis is frequently made clinically. Antimicrobial stewardship committees in partnership with prescribers need to define indications for echinocandin use that encompasses both straightforward culture-proven infections, and more nuanced indications that are not microbiologically-proven.

We also found that IV vancomycin was frequently used relative to MRSA AR events in Hospital A and B. Indications for IV vancomycin use include treatment of endocarditis caused by corynebacteria, enterococci, staphylococci, and streptococci;[25] staphylococcal infections (eg bloodstream infections, bone infections, lower respiratory tract infections, skin and skin structure infections);[26] central nervous system infections (eg brain abscess, epidural abscess, bacterial meningitis, cerebrospinal fluid shunt infection);[27] endophthalmitis;[28] peritonitis in the setting of peritoneal dialysis;[29] and prosthetic joint infection.[30] IV vancomycin is also indicated for surgical prophylaxis of patients at high risk for MRSA infection.[31] Infections for which IV vancomycin are indicated are sometimes not associated with positive cultures, as with some bone and joint infections, pneumonia, cellulitis, central nervous system infections, and prosthetic joint infections. Moreover, IV vancomycin is indicated for empiric coverage of MRSA or methicillin-resistant *S. epidermidis*. Antimicrobial stewardship committees need to define indications for IV vancomycin use for which its use is appropriate. Nevertheless, the IV vancomycin/MRSA ratio can be used by antimicrobial stewardship teams in educating prescribers about the relative

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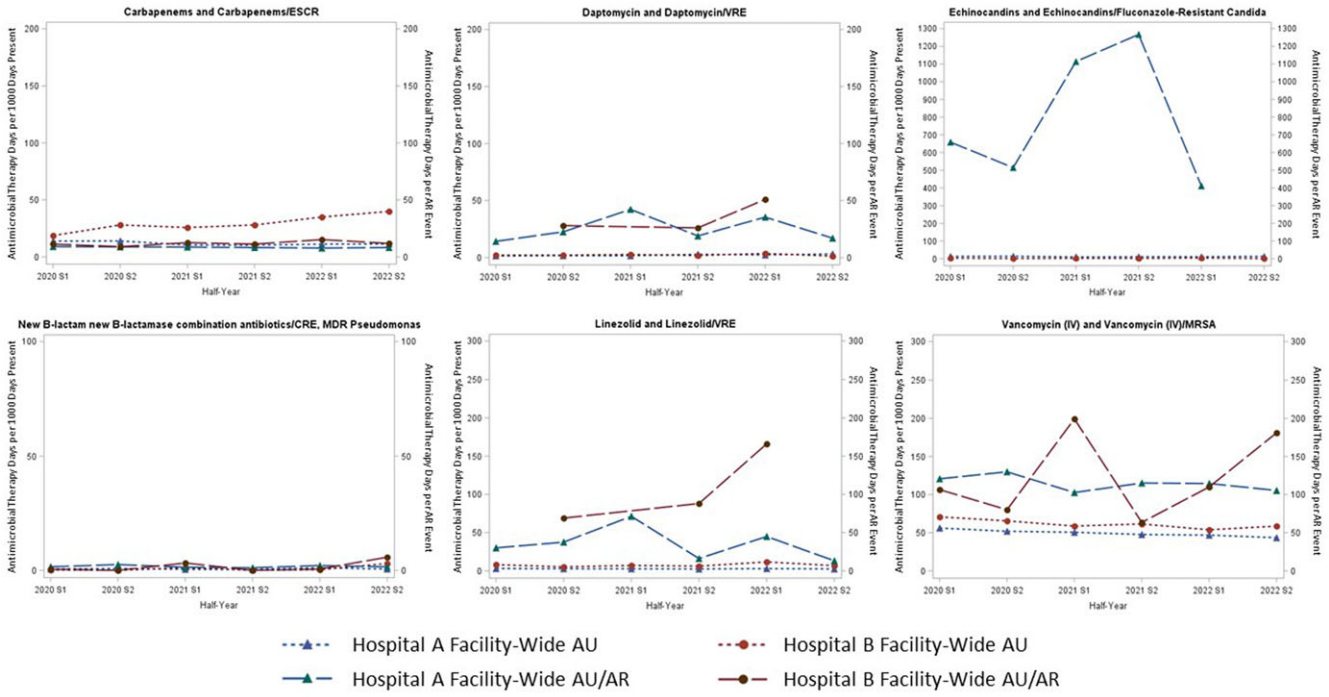

Figure 1. Trends for semi-annual facility-wide AU and AU/AR ratios in Hospital A and Hospital B from 2020 to 2022. AU – antimicrobial use; AR, antimicrobial resistance; IV, intravenous; ESCR, extended-spectrum cephalosporin-resistant *Escherichia coli* and *Klebsiella pneumoniae*/*oxytoca*; VRE, vancomycin-resistant *Enterococcus*; CRE, carbapenem-resistant Enterobacterales; MDR, multidrug-resistant; MRSA, methicillin-resistant *Staphylococcus aureus*.

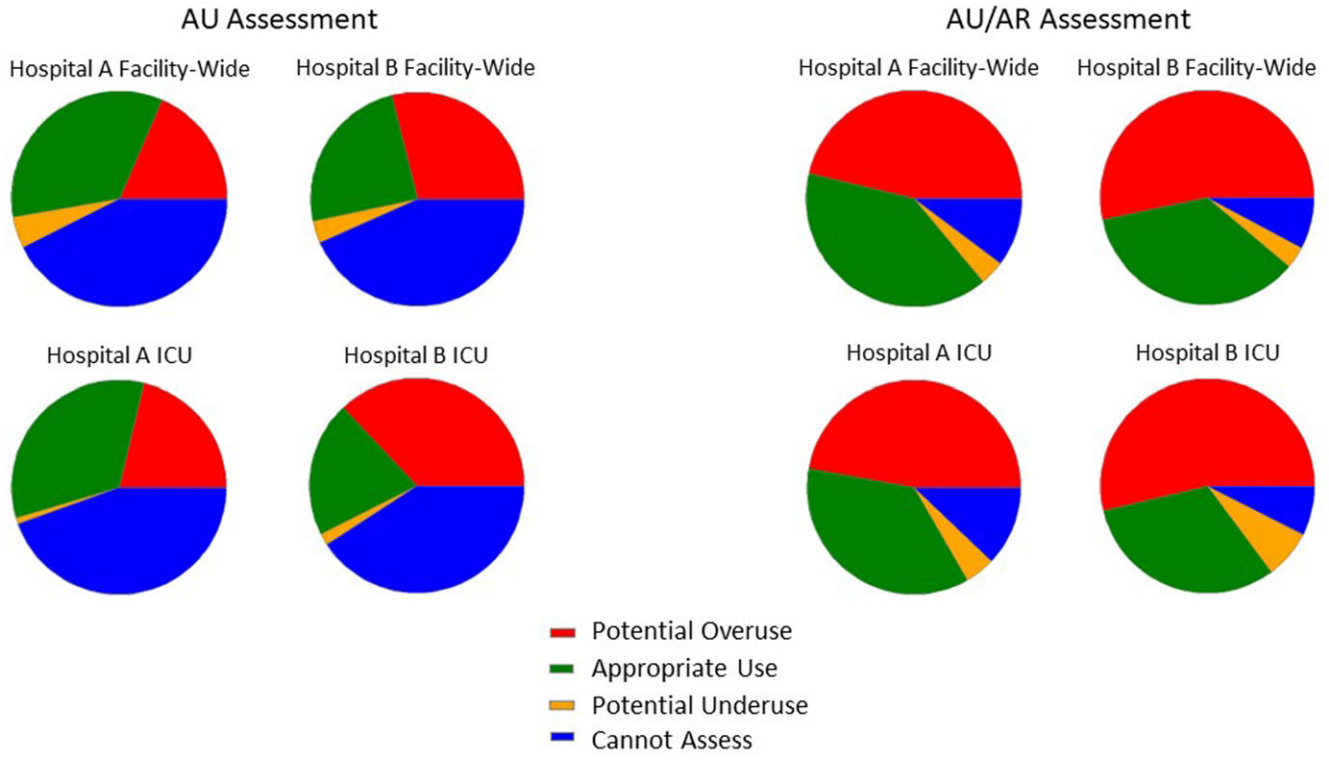

Figure 2. Assessment of AU and AU/AR ratios at Hospital A and Hospital B by antimicrobial stewardship committee members excluding pairs of AU and AU/AR ratios for which AU/AR ratios were not computable. AU, antimicrobial use; AR, antimicrobial resistance; ICU, intensive care unit.

paucity of MRSA events compared to the degree of vancomycin use, and can be used to measure the effects of interventions to promote more judicious use.

Linezolid was frequently used relative to VRE AR events in Hospital B facility-wide, leading the majority of respondents to indicate potential overuse. Linezolid AU was also significantly

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greater in Hospital B compared to Hospital A. These results should prompt an examination of linezolid AU in Hospital B to determine appropriateness of use.

Appropriate linezolid use includes treatment of VRE,[32] pneumonia caused by *Streptococcus pneumoniae* and *S. aureus*,[33] skin and skin structure infections caused by *S. aureus*, *S. pyogenes*, or *S. agalactiae*,[34] drug-resistant tuberculosis,[35] select non-tuberculous mycobacteria,[36] and nocardiosis.[37] Notably, these conditions may not be associated with positive cultures as in the case of pneumonia or skin and skin structure infections. Indications for linezolid need to be formalized by antimicrobial stewardship committees to inform audit and feedback efforts.

Carbapenems were frequently used relative to ESCR AR events in the medical ICU of Hospital A and the ICU of Hospital B, leading the majority of respondents to indicate potential overuse of carbapenems in these settings. Indications for carbapenems include sepsis and septic shock,[38] complicated urinary tract infection,[39] intra-abdominal infection,[40] healthcare-associated or high-risk community-acquired infection,[10] bacterial meningitis,[41] and moderate to severe skin and skin structure infection.[42] These conditions may or may not be associated with positive cultures, and use within these indications would be considered appropriate. However, as antimicrobials reserved for the treatment of antibiotic-resistant Gram-negative organisms such as ESCR Enterobacterales,[10] appropriateness of carbapenem use can be further classified as appropriate but suboptimal versus appropriate and optimal. Appropriate but suboptimal use can be defined as carbapenem administration when more narrow-spectrum antimicrobials would be sufficient based on pre-test probabilities for antimicrobial resistance in the case of empiric therapy, or culture results in the case of definitive therapy.[43] Antimicrobial stewardship teams need to compile a list of indications for which carbapenem use is appropriate, and develop criteria for appropriate but suboptimal carbapenem use, versus appropriate and optimal carbapenem use.

Restricted antimicrobial authorization seems to contribute to the numerically lower facility-wide AU/AR ratios for carbapenems/ESCR and new beta-lactam beta-lactamase combination antibiotics/MDRPA plus CRE in Hospital A. However, the numerically higher facility-wide AU/AR ratios for echinocandins/FRC in Hospital A suggest that there are limits to the effectiveness of antimicrobial restriction and that audits are needed to guide further stewardship efforts. In Hospital B, restricted antimicrobial authorization also likely contributes to the numerically lower facility-wide AU/AR ratio for beta-lactamase combination antibiotics/MDRPA plus CRE. The numerically higher AU/AR ratios for linezolid/VRE in Hospital B, and IV vancomycin/MRSA in Hospital A and B, may be due in part to the lack of restrictions on ordering and administration.

The strengths of our study include use of AU and AR metrics already reported to NHSN, benchmarking of AU to AR that seems more instructive and actionable than AU metrics in isolation, and comparison of AU and AU/AR values in a university hospital and a community hospital. It, however, has limitations. First, AR events are limited to select drug-resistant microbes, which restricts the number of computable AU/AR ratios. However, this paper provides a foundation that can inform the development of other AU/AR ratios for a greater number of antimicrobials, and highlights the value of adjusting AU for AR when comparing AU across hospitals. Second, we cannot definitively assess appropriateness of AU based on AU/AR ratios alone. Indications for each antimicrobial need to be compiled by antimicrobial stewardship committees, and audits of AU need to be performed to determine appropriateness of use. However, numerically higher AU/AR values may indicate an excess of empiric coverage and motivate the performance of audits. Third, AR events are assigned to the location where samples are collected, not necessarily where patients are treated. For example, AR events identified from samples collected in the emergency department would be assigned to that department, not the inpatient unit that would provide antimicrobial therapy for the patient after admission, which would result in inflation of AU/AR ratios in receiving units. However, facility-wide AU/AR ratios would be less susceptible to this inflation and can still be useful in identifying potential excesses of antimicrobial use. Fourth, AR events can be rare or absent, resulting in widely fluctuating or non-computable AU/AR ratios, especially at the location level. However, when computable, AU/AR ratios seem more informative than AU metrics in isolation. Fifth, this was a two-center study in a single health system and its findings may not be generalizable. However, since both AU and AR metrics used for this study are already reported to NHSN, our proposed metric can be replicated in other hospitals for multicenter studies comparing AU/AR ratios. Sixth, we did not account for COVID surges in this paper since it was beyond its scope. We have a separate paper using a different dataset wherein we found that AU for broad-spectrum antibacterial agents predominantly used for hospital-onset infections was greater in COVID patients compared to non-COVID patients from March to December 2020.[44] This analysis was not possible with the current paper since NHSN does not stratify AU by COVID status.

In summary, we compared select conventional AU metrics to AU/AR ratios in two hospitals and found that antimicrobial stewardship committee members were more able to assess antimicrobial use and identify potential overuse based on AU/AR values compared to AU values alone. Future directions in our hospitals would include updating AU/AR ratios yearly and calculating it facility-wide and for each inpatient unit. AU/AR ratios can be readily calculated by facilities that already monitor AU and AR events using NHSN methods. It can be used to benchmark AU for interhospital comparisons and assist stewardship committees in identifying potential overuse of specific antimicrobial agents.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/ice.2024.210

Data availability statement. Raw data were generated at RUSH University Medical Center and RUSH Oak Park Hospital. Derived data supporting the findings of this study are available from the corresponding author (Carlos A.Q. Santos) upon request.

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Competing interests. All authors report no conflicts of interest in this article.

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