Infection and Drug Resistance

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ORIGINAL RESEARCH

Prevailing Antibiotic Resistance Patterns in Hospitalized Patients with Urinary Tract Infections in a Vietnamese Teaching Hospital (2014 – 2021)

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Purpose: In a Vietnamese teaching hospital, this study examined the prevalence and patterns of antimicrobial resistance (AMR) of common bacteria isolated from hospitalized patients with urinary tract infections (UTIs) between 2014 and 2021.

Methods: From 4060 urine samples collected, common pathogens were isolated using quantitative culture on brilliance UTI Clarity agar and blood agar. Bacterial identification, antimicrobial susceptibility testing, and multidrug resistance (MDR) classification followed standardized techniques. Bacteria with a frequency of less than 2% were excluded. Statistical analysis was performed using R software, with the chi-square test applied and significance set at $p < 0.05$.

Results: Of 4060 urine samples collected, 892 (22.0%) had positive results for common infections. Gram-negative bacteria predominated (591/892; 66.3%), with *Escherichia coli* being the most prevalent (336/892; 37.7%). *Enterococcus* spp. (152/892; 17.0%) was the leading Gram-positive pathogen. Some antibiotics had significant resistance rates, especially in Gram-negative bacteria, with ampicillin having the greatest resistance rate (92.8%). Carbapenems and nitrofurantoin remained generally effective. Among Gram-positive bacteria, high resistance was seen for macrolides ranging from 85.5% (azithromycin) to 89.8% (erythromycin), and for tetracyclines, ranging from 0% (teicoplanin) to 85.2% (tetracycline). There was no resistance to tigecycline and teicoplanin, indicating their potential efficacy against multidrug resistance (MDR) bacteria causing UTIs. MDR rates were higher in Gram-negative bacteria (64.8% versus 43.5%), with *Klebsiella pneumoniae* having the highest rate (78.7%).

Conclusion: This study underscores the urgent need for ongoing surveillance of AMR patterns in Vietnam and emphasizes the significance of efficient infection prevention methods, prudent use of antibiotics, and targeted interventions to combat antimicrobial resistance.

Keywords: urinary tract infections, UTIs, antimicrobial resistance, multidrug resistance, MDR, Vietnam

Received: 8 October 2024
Accepted: 22 January 2025
Published: 31 January 2025

Introduction

Urinary tract infections are a significant and widespread health issue, significantly impacting healthcare systems globally. These infections affect millions of individuals yearly, causing substantial discomfort, disrupting daily activities, and leading to considerable healthcare costs. Moreover, if not adequately managed, UTIs can escalate into severe, life-threatening complications.[1] Gram-negative bacteria like *Escherichia coli* (*E. coli*) and *Klebsiella pneumoniae* (*K. pneumoniae*) are the main causes of UTIs. However, the etiological spectrum also includes Gram-positive bacteria and fungi. Thus, a more excellent range of possible pathogens can be considered. Antimicrobial resistance in UTIs bacteria is becoming more dangerous to public health. The bacterial evolution of resistance mechanisms gradually compromises antibiotic therapy's vital role in treating UTIs. Improving infection control measures, judicious antibiotic use, and improved diagnostics are necessary to address this issue.[2] There is a lot of interest in UTIs research in Vietnam, especially in figuring out how common they are in different age groups, from children to seniors. The frequency of UTIs and the current state of antimicrobial resistance in the Vietnamese community remains poorly understood despite this interest. There is an urgent need to fill the gap. Extensive data collection on the occurrence and distribution of different UTIs types among different patient demographics is first required to determine the specific challenges in Vietnam. Furthermore, the development of targeted antibiotic treatment depends on understanding the resistance patterns exhibited by the bacteria that cause UTIs. Antibiotics should be used responsibly to preserve their effectiveness in treating future medical conditions. Considering the most prevalent UTIs pathogens and their AMR profiles helps to understand the landscape of bacterial drug resistance. This research is instrumental in controlling the spread of resistance; effective infection control practices and prudent antibiotic use are critical in limiting the transmission of antimicrobial-resistant bacteria within healthcare and community settings. Moreover, safeguarding the effectiveness of antibiotics is essential for managing UTIs and other bacterial infections. By investigating the prevalence and AMR patterns of common Gram-positive and Gram-negative bacteria isolated from hospitalized patients diagnosed with UTIs in a Vietnamese teaching hospital, this study seeks to close the information gap. Our study results will guide initiatives to improve antibiotic stewardship, ultimately maximizing the efficient use of antibiotics in Vietnam's healthcare system. It will also help clarify the frequency of UTIs and AMR in Vietnam, which will help develop practical ways to manage UTIs.

Materials and Methods

Study Setup and Design

This retrospective cross-sectional study was conducted at the Department of Microbiology, Military Hospital 103, Vietnam, from January 2014 to December 2021. The study analyzed urine samples from hospitalized patients with suspected UTIs. The methodology used hospital medical records to gather patient demographic and clinical information.

Methodology

Urine samples, including clean-catch midstream and catheterized specimens, were collected following the protocols outlined in the Clinical Microbiology Procedures Handbook, 4th Edition.[3] Each sample was inoculated using a 1-μL sterile loop onto Brilliance UTI Clarity agar (Oxoid, England) and blood agar (Oxoid, England) and incubated under aerobic conditions at 37°C for 18–24 hours. Bacterial colonies were classified as uropathogens if they reached a threshold of $\geq 10^4$ CFU/mL for single isolates or $\geq 10^5$ CFU/mL when up to two types of bacterial morphologies were observed. Bacterial species were identified using standard biochemical methods, and antimicrobial susceptibility testing was performed using the Kirby-Bauer disk diffusion method, following CLSI guidelines. Multidrug resistance (MDR) bacteria were defined as nonsusceptible to at least one agent in three or more antimicrobial categories.[4] Bacteria that tested positive and had a frequency of less than 2% were taken out of the dataset.

Analytical Statistics

R software 4.3.2 was used to conduct statistical analysis. The chi-square test was employed for the statistical analysis, with a significance level set at $p < 0.05$ for all tests. Demographic data, including age, sex, bacterial isolates, and antimicrobial susceptibility test results of admitted patients, were analyzed.

Results

Epidemiological Characteristics of UTIs Samples and Patient Demographics

A total of 4060 UTIs samples were analyzed, with 892 (22.0%) testing positive for pathogens. Gram-negative bacteria were the majority (66.3%), with *Escherichia coli* being the most prevalent. Gram-positive bacteria accounted for 33.7% of isolates, with *Enterococcus* spp. being the most common. The predominant bacteria included *E. coli* (37.7%), *Enterococcus* spp. (17.0%), *Pseudomonas aeruginosa* (15.2%), *Klebsiella pneumoniae* (10.0%), *Streptococcus viridans* (10.0%), *Staphylococcus aureus* (3.7%), and *Acinetobacter baumannii* (3.4%) (Figure 1A). Males (58.7%) had more positive cultures than females (41.3%) ((Figure 1B). Most positive pathogens were found in the Internal Medicine (32.4%), Infectious Disease (28.7%), Surgical (27.0%), and ICU (11.9%) wards (Figure 1C). Adults aged 41–65 years had the highest proportion of cases (40.8%), followed by those over 66 (39.7%), aged 16–40 (18.5%), and aged 0–15 (1.0%) (Figure 1D).

Gram-Negative Bacteria Isolated from UTIs Patients and Their Patterns of Antimicrobial Resistance

The susceptibility testing of Gram-negative bacteria revealed varying resistance patterns across all UTIs samples. Ampicillin exhibited the highest resistance rate (92.8%), followed by levofloxacin (78.3%), ticarcillin/clavulanic acid (76.9%), and ceftriaxone (76.0%). Conversely, imipenem (35.0%), meropenem (34.3%), amikacin (24.7%), nitrofurantoin (18.5%), colistin (9.7%), and ertapenem (5.6%) were the most effective antibiotics. Specific Gram-negative bacteria displayed concerning resistance patterns. *K. pneumoniae* showed 100% antimicrobial resistance, including tobramycin,

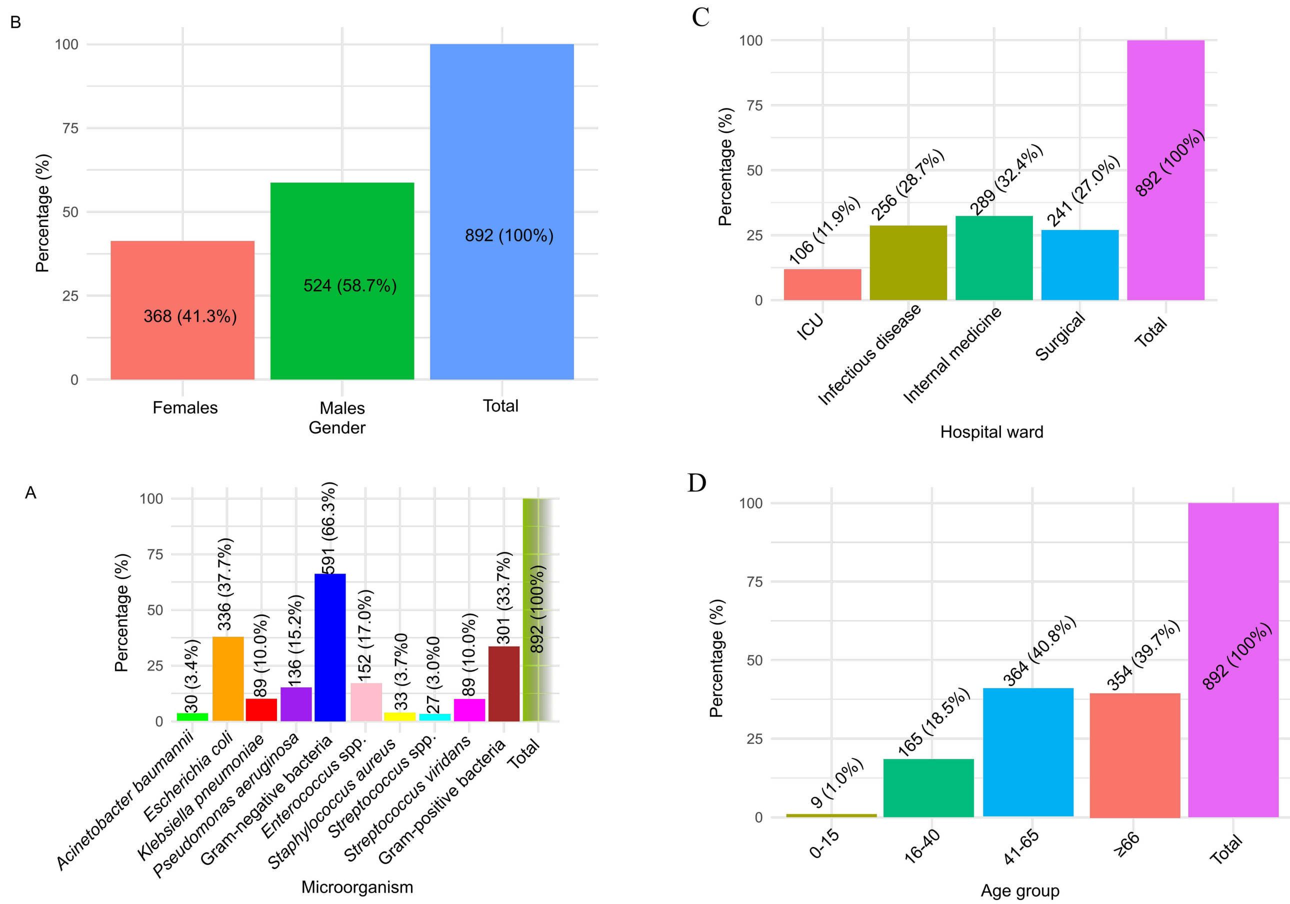

Figure 1 Demographics of hospitalized patients with urinary tract infections in a Vietnamese teaching hospital. (**A**) Distribution of isolates by microorganism, (**B**) Distribution of isolates by gender, (**C**) Distribution of isolates by hospital ward, (**D**) Distribution of isolates by age group.

https://doi.org/10.2147/IDR.S499804

ampicillin, piperacillin, and aztreonam. A similar pattern of aztreonam resistance was observed in *A. baumannii. E. coli* displayed the highest resistance rates to ampicillin (90.7%) and piperacillin (84.6%). *P. aeruginosa* exhibited the highest resistance to trimethoprim/sulfamethoxazole (93.3%). Colistin emerged as the most effective antibiotic for *A. baumannii* infections, with no resistance observed in this study (Table 1). Colistin also demonstrated high efficacy against *P. aeruginosa*, with a resistance rate of only 9.3%. Nitrofurantoin and ertapenem were particularly effective against *E. coli* infections, with resistance rates below 5%. Although ertapenem and colistin demonstrated a reasonable level of efficacy against *K. pneumoniae*, the persistent problem posed by AMR is underscored by their respective resistance rates of 17.6% and 20.0%.

Antimicrobial Resistance Patterns of Gram-Positive Pathogens Isolated from UTIs Patients

Of all drugs examined for Gram-positive bacteria, erythromycin showed the highest resistance rate (89.8%), followed closely by norfloxacin (85.7%) across all UTIs samples. Azithromycin and clindamycin each showed a resistance rate of 85.5%, and tetracycline had a similar rate (85.2%). Among fluoroquinolones, moxifloxacin had a lower resistance rate (46.3%) compared to ciprofloxacin (73.2%) and levofloxacin (68.4%). Vancomycin and teicoplanin, two glycopeptides, showed modest resistance rates of 5.1% and 0%, respectively, demonstrating their efficacy against Gram-positive bacteria. Linezolid also had a low resistance rate (9.6%), while tigecycline showed no resistance, suggesting its potential as an alternative therapy. There were high rates of resistance found for *Enterococcus* spp. with macrolides (erythromycin: 90.6%, azithromycin: 85.7%) and clindamycin (93.7%). All the isolates were sensitive to tigecycline, which proved efficient against *Enterococcus* species. For *S. aureus*, norfloxacin showed the highest resistance (100%), while tigecycline, teicoplanin, linezolid, nitrofurantoin, vancomycin, and quinupristin/dalfopristin exhibited 0% resistance (Table 2).

Pathogen Resistance Rate in UTIs Patients Admitted to Both Surgery and Non-Surgical Wards

In this investigation, the AMR rates of Gram-negative bacteria isolated from surgical ward patients were greater than those found in non-surgical ward patients. This difference was observed for several antibiotics, including amikacin, gentamicin, amoxicillin/clavulanic acid, cefepime, cefotaxime, and ceftazidime. Specifically, surgical wards had considerably higher rates of resistance to cefepime ($p = 0.0353$) and gentamycin ($p = 0.0433$) (Figure 2A). Conversely, tobramycin, piperacillin, ticarcillin/clavulanic acid, ceftriaxone, and nitrofurantoin showed that patients in non-surgical wards had greater rates of resistance. Gram-positive bacteria causing UTIs exhibited varying resistance patterns. Surgical wards had higher rates of antimicrobial resistance than non-surgical wards for several antibiotics, including azithromycin, erythromycin, ciprofloxacin, ofloxacin, tetracycline, and clindamycin. In addition, resistance rates for cefoxitin (100.0% versus 57.1%), moxifloxacin (58.8% versus 37.5%), linezolid (21.3% vs 3.9%), quinupristin/dalfopristin (43.6% versus 35.3%), and trimethoprim/sulphamethoxazole (50.0% versus 35.0%) were notably higher in surgical wards compared to non-surgical wards. Levofloxacin showed similar resistance rates between both wards (68.8% versus 68.2%). In contrast, doxycycline and rifampicin showed slightly higher resistance in the non-surgical ward. Based on statistical analysis, there were substantial variations in the resistance rates to linezolid ($p = 0.0002$) and erythromycin ($p = 0.0281$) between the wards (Figure 2B).

The Percentage of Microorganisms with Multidrug Resistance Found in UTIs Patients

The overall MDR rate of Gram-negative bacteria was greater (64.8%) than that of Gram-positive bacteria (43.5%). Among Gram-negative bacteria, *K. pneumoniae* displayed the highest MDR rate (78.7%), followed by *P. aeruginosa* (77.2%) and *A. baumannii* (56.5%). The MDR rate of 60.0% for *E. coli* was comparatively lower but nevertheless considerable (Figure 3A). Similarly, MDR rates varied among Gram-positive bacteria. *Enterococcus* spp. had the highest rate (55.9%), followed by *S. aureus* (45.5%), *Streptococcus* spp. (37.0%), and *Streptococcus viridans* (23.6%) (Figure 3B).

https://doi.org/10.2147/IDR.S499804

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Table 1 Antimicrobial Resistance Patterns of Common Gram-Negative Bacteria Isolated from UTI Patients at a Vietnamese Teaching Hospital

Antimicrobials Class	Antimicrobial Agents	*Acinetobacter baumannii*		*Escherichia coli*		*Klebsiella pneumoniae*		*Pseudomonas aeruginosa*		Total		
		N	R (%)	N	R (%)	N	R (%)	N	R (%)	N	R (%)	p-value
Aminoglycosides	**Amikacin**	13	23.1	299	8.7	79	22.8	123	65.0	514	24.7	< 0.0001
	Gentamicin	22	59.1	268	41.0	80	52.5	121	76.9	491	52.5	< 0.0001
	Tobramycin	21	42.9	23	39.1	4	100.0	117	76.9	165	67.9	0.0001
Penicillin	**Ampicillin**	NA	NA	281	90.7	79	100.0	NA	NA	360	92.8	0.0051
	Piperacillin	20	60.0	13	84.6	3	100.0	115	71.3	151	71.5	0.3086
Beta-lactamase inhibitors	**Amoxicillin/ clavulanic acid**	3	66.7	311	34.4	83	71.1	NA	NA	397	42.3	< 0.0001
	Piperacillin/ tazobactam	22	72.7	12	16.7	78	67.9	14	14.3	126	57.9	< 0.0001
	Ticarcillin/ clavulanic acid	18	55.6	9	22.2	NA	NA	120	84.2	147	76.9	< 0.0001
Cephalosporins	**Cefepime**	25	72.0	302	47.4	83	78.3	124	72.6	534	59.2	< 0.0001
	Cefotaxime	NA	NA	299	71.2	83	78.3	NA	NA	382	72.8	0.2007
	Ceftazidime	26	69.2	318	58.2	85	80.0	124	75.0	553	65.8	0.0001
	Ceftriaxone	6	66.7	38	76.3	6	83.3	NA	NA	50	76.0	0.7923
Fluoroquinolones	**Ciprofloxacin**	24	70.8	306	68.0	83	80.7	126	84.1	539	73.8	0.0023
	Levofloxacin	24	62.5	36	63.9	5	80.0	124	85.5	189	78.3	0.0085
	Norfloxacin	NA	NA	276	64.5	78	75.6	12	66.7	366	66.9	0.1813
Monobactams	**Aztreonam**	8	100.0	46	63.0	5	100.0	33	66.7	92	69.6	0.0806
Carbapenems	**Ertapenem**	NA	NA	269.0	4.1	34.0	17.6	NA	NA	303	5.6	0.0012
	Meropenem	25	52.0	306	8.2	85	62.4	124	75.8	540	34.3	< 0.0001
	Imipenem	24	45.8	299	9.0	82	62.2	127	76.4	532	35.0	< 0.0001
Nitrofuran	**Nitrofurantoin**	NA	NA	268	3.0	78	71.8	NA	NA	346	18.5	< 0.0001
Folate pathway antagonists	**Trimethoprim/ sulfamethoxazole**	21	57.1	281	73.7	79	69.6	15	93.3	396	72.7	0.0982
Lipopeptides	**Colistin**	14	0.0	8	25.0	5	20.0	86	9.3	113	9.7	0.2358

Note: p-value was calculated by the Chi-square test.
Abbreviations: N, number of tested isolates; R, Resistance; NA, Not applicable.

Table 2 Antimicrobial Resistance Patterns of Common Gram-Positive Bacteria Isolated from UTI Patients at a Vietnamese Teaching Hospital

Antimicrobials Class	Antimicrobial Agents	*Enterococcus* spp.		*S. aureus*		*Streptococcus* spp.		Streptococcus Viridans		Total		
		N	%R	N	%R	N	%R	N	%R	N	%R	p-value
Aminoglycosides	**Gentamicin**	NA	NA	17	35.3	NA	NA	NA	NA	17	35.3	0.2253
Macrolides	**Azithromycin**	7	85.7	11	63.6	6	100.0	45	88.9	69	85.5	0.1284
	Erythromycin	128	90.6	14	78.6	14	92.9	30	90.0	186	89.8	0.5392
Cephamycins	**Cefoxitin**	NA	NA	16	62.5	NA	NA	NA	NA	16	62.5	0.3173
Fluoroquinolones	**Ciprofloxacin**	141	77.3	25	40.0	9	55.6	30	86.7	205	73.2	0.0002
	Levofloxacin	138	72.5	19	31.6	20	60.0	57	73.7	234	68.4	0.0025
	Norfloxacin	31	87.1	5	100.0	14	78.6	34	85.3	84	85.7	0.6892
	Moxifloxacin	14	64.3	20	35.0	7	42.9	NA	NA	41	46.3	0.2367
	Ofloxacin	6	83.3	11	36.4	4	75.0	50	82.0	71	74.6	0.017
Tetracyclines	**Tetracycline**	121	86.8	15	86.7	13	76.9	20	80.0	169	85.2	0.7056
	Doxycycline	63	57.1	12	16.7	15	20.0	32	15.6	122	37.7	0.0001
	Tigecycline	102	0	15	0	4	0	NA	NA	121	0.0	< 0.0001
Glycopeptides	**Teicoplanin**	36	0	6	0	1	0	NA	NA	43	0.0	< 0.0001
	Vancomycin	139	12.2	17	0	20	15.0	58	13.8	234	5.1	0.7935
Oxazolidinones	**Linezolid**	118	10.2	23	0	14	0.0	33	18.2	188	9.6	0.0789
Nitrofuran	**Nitrofurantoin**	132	28.8	15	0	7	14.3	10	70.0	164	28.0	0.0016
Streptogramins	**Quinupristin/dalfopristin**	123	44.7	14	0	11	63.6	24	8.3	172	37.2	< 0.0001
Ansamycins	**Rifampicin**	8	25.0	15	6.7	5	40.0	5	40.0	33	21.2	0.253
Lincosamides	**Clindamycin**	16	93.7	22	68.2	9	88.9	36	91.7	83	85.5	0.06
Folate pathway antagonists	**Trimethoprim/sulfamethoxazole**	NA	NA	24	37.5	NA	NA	NA	NA	24	37.5	0.2207

Note: p-value was calculated by the Chi-square test.
Abbreviations: N, number of tested isolates; R, Resistance; NA, Not applicable.

https://doi.org/10.2147/IDR.S499804

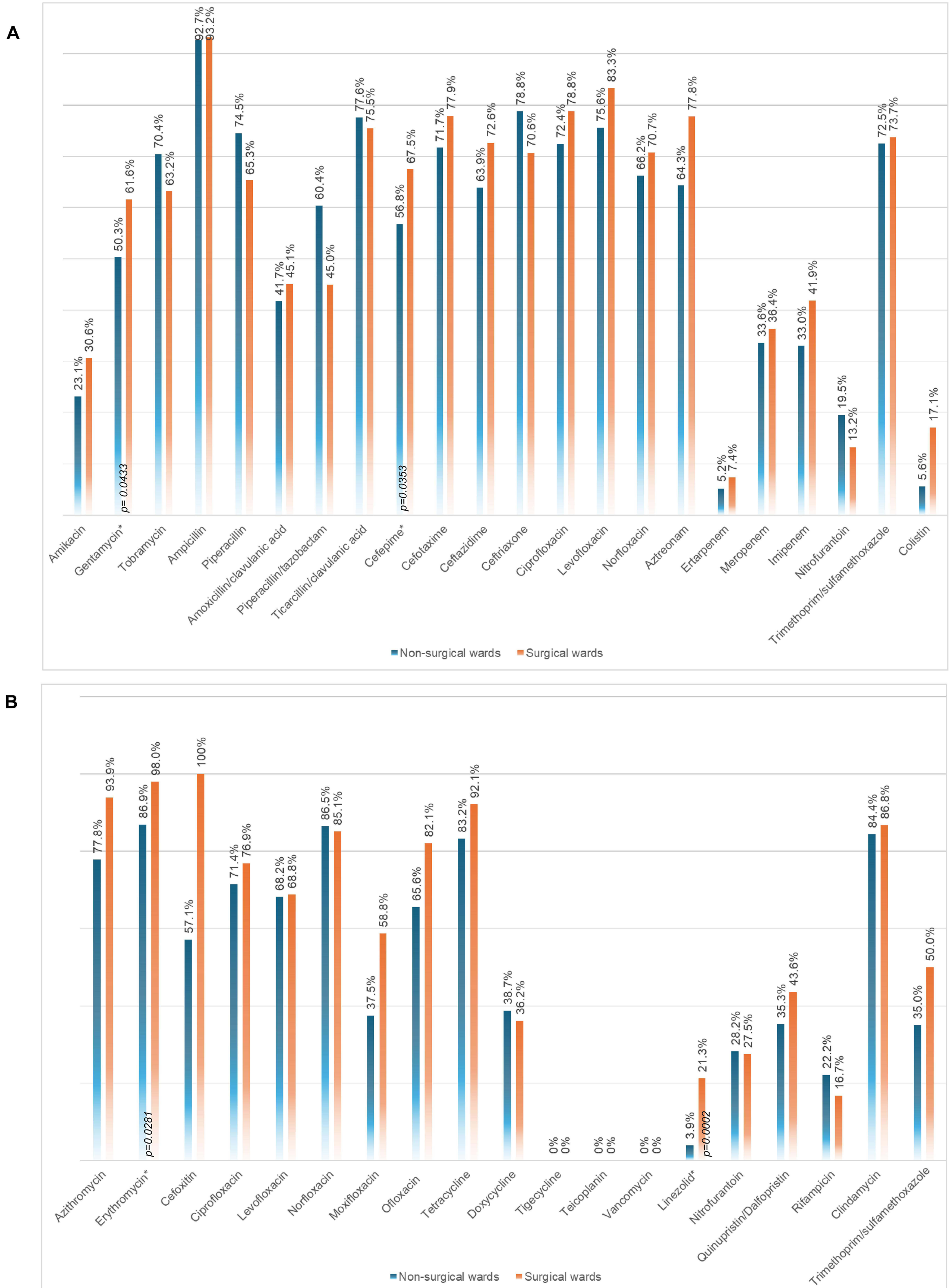

Figure 2 Antimicrobial resistance to selected antibiotics of common pathogens among hospital wards. (**A**) Gram-negative bacteria, (**B**) Gram-positive bacteria; p-value was calculated using Chi-square test.

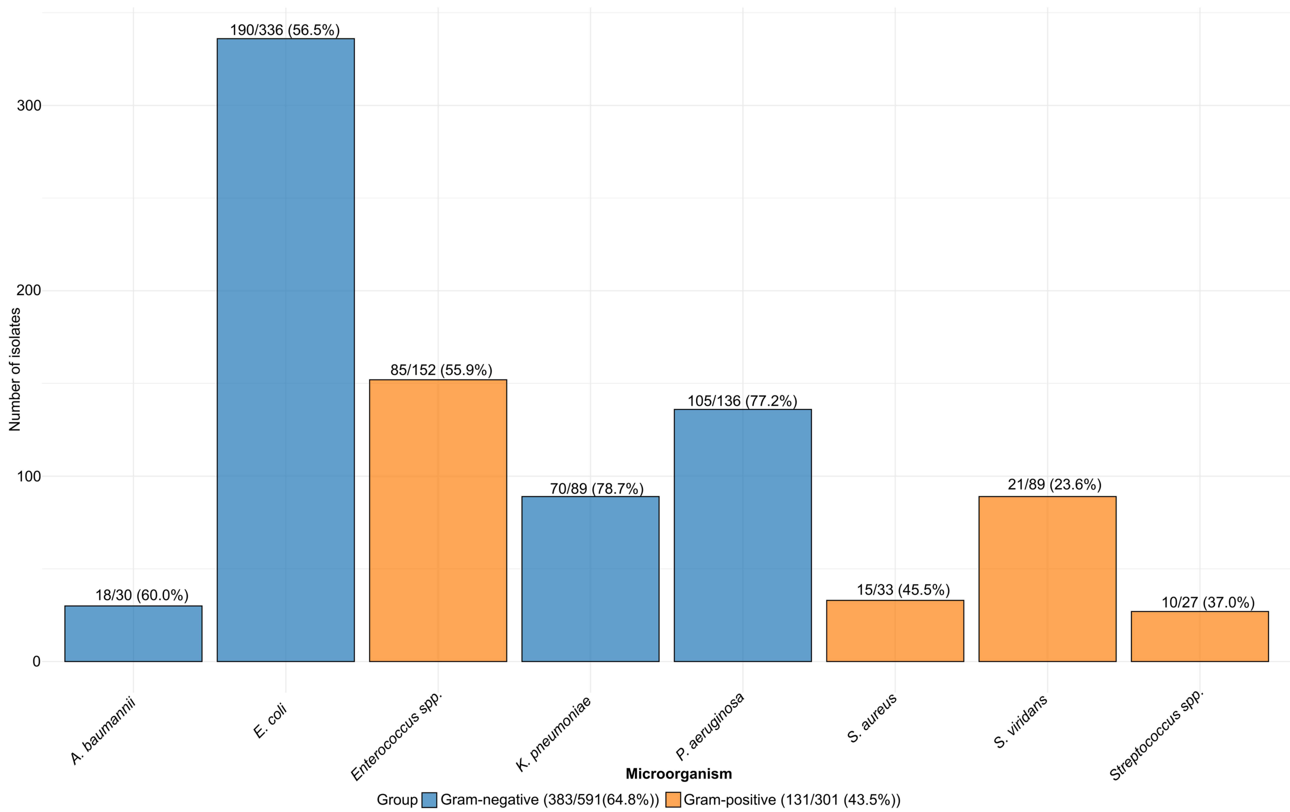

Figure 3 Multidrug resistance rate of common bacteria isolated from patients with urinary tract infections admitted to a Vietnamese teaching hospital from 2014 to 2021..
Abbreviation: MDR, Multidrug resistance.

Discussion

This study reported a 22.0% positive culture rate for UTIs. Literature suggests a wide range of UTIs prevalence depending on the population studied and the diagnostic criteria used. Studies in outpatients often report lower rates (around 10%), while hospitalized patients might have higher positivity rates (up to 41%).[5,6] Our positive culture rate was similar to that of Swetha et al, 2023 in India, with a 20% positive rate.[7]

The dominance of Gram-negative bacteria (66.3%) with *E. coli* as the most prevalent isolate (37.7%) aligns with established knowledge from a study by Carlo Zagaglia et al.[8] The emergence of *Enterococcus* spp. (17.0%) as the leading Gram-positive pathogen was noteworthy. While *E. coli* was often the most common pathogen, some studies found an increase in *Enterococcus* spp. as a significant uropathogen, indicating that there might be geographical variations.[9]

Higher UTIs prevalence observed in Internal Medicine, Infectious Disease, and Surgical wards aligned with previous research, suggesting increased risk in these patient populations due to underlying conditions and potential catheter use.[10,11] The trend towards UTIs in older adults (41–65 and over 66 years old) was consistent with existing literature, which attributes this to physiological changes and comorbidities.[12]

Our analysis showed a higher proportion of UTIs in males (58.7%) compared to females (41.3%), which is interesting, while most studies highlighted a predominance of females.[13,14] The discrepancy in findings could be attributed to variations in the study population or methodological factors, necessitating further investigation. This study and other research underscore the significance of examining specific patient risk factors beyond age and gender, encompassing medical history, antibiotic use before admission, and prior UTIs.

Evaluating AMR profiles of isolated uropathogens is vital, in keeping with the constraints of our investigation and highlighting a critical topic for future investigation.[15] Our investigation of the AMR patterns of common Gram-negative bacteria isolated from patients with UTIs revealed alarming patterns and emphasized the necessity of continued antibiotic management. High resistance rates were observed for ampicillin (92.8%), levofloxacin (78.3%), ticarcillin/clavulanic acid (76.9%), and ceftriaxone (76.0%), consistent with a study on increasing antimicrobial resistance.[16] The extensive use of these antibiotics likely contributed to the emergence of resistant strains.

On the other hand, the most effective drugs were imipenem (35.0%), meropenem (34.3%), amikacin (24.7%), nitrofurantoin (18.5%), colistin (9.7%), and ertapenem (5.6%). These results are consistent with studies highlighting the usefulness of carbapenems and nitrofurantoin for UTIs. Carbapenems must be used carefully to maintain efficacy as a last-resort treatment for severe infections.[17]

Our research identified resistance patterns in specific microorganisms. Notably, the emergence of MDR *K. pneumoniae* was underscored by its complete resistance to various antimicrobial agents. This finding corresponds to the increasing concerns regarding MDR *K. pneumoniae* in UTIs, which pose a significant challenge for healthcare institutions.[18] Comparable patterns were noted in *E. coli*, which was resistant to both ampicillin and piperacillin, and *A. baumannii*, which was resistant to aztreonam, highlighting the need for continued monitoring and the creation of novel antibiotics to combat MDR infections.

Encouragingly, our study found no resistance to colistin in *A. baumannii* infections, but this might not be generalizable to all settings, and potential side effects necessitate careful monitoring of resistance trends of colistin. The analysis of antimicrobial resistance in Gram-positive bacteria from UTIs reveals concerning trends while highlighting the continued effectiveness of some antibiotics. High resistance rates were identified for erythromycin (89.8%), azithromycin (85.5%), clindamycin (85.5%), tetracycline (85.2%), norfloxacin (85.7%), ciprofloxacin (73.2%), and levofloxacin (68.4%), consistent with the study of Márió Gajdács et al reporting increasing resistance among Gram-positive bacteria, particularly to macrolides and fluoroquinolones.[19]

Overuse of these antibiotics was likely to contribute to the emergence of resistant strains. Conversely, teicoplanin, vancomycin, and linezolid demonstrated exceptional effectiveness, with resistance rates of 0%, 5.1%, and 9.6%, respectively, emphasizing the importance of preserving these antibiotics for severe infections caused by MDR Gram-positive bacteria.[20] No resistance to tigecycline was observed in any tested Gram-positive bacteria, suggesting its potential as a valuable alternative for treating MDR infections. However, further research is necessary to determine its optimal clinical application.

Variations in susceptibility patterns among specific Gram-positive bacteria were also identified. *Enterococcus* spp. exhibited high resistance to macrolides, lincosamides, and fluoroquinolones, highlighting the emergence of MDR Enterococcus as a growing concern. Conversely, tigecycline displayed excellent activity against all Enterococcus isolates. *S. aureus* demonstrated a high resistance rate to norfloxacin but remained susceptible to tigecycline, teicoplanin, linezolid, nitrofurantoin, vancomycin, and quinupristin/dalfopristin.

This study investigated antimicrobial resistance patterns in common pathogens isolated from UTIs patients in surgical and non-surgical wards, revealing significant variations. Higher resistance rates were found in surgical wards for amikacin, gentamicin, ampicillin, amoxicillin/clavulanic acid, cefepime, cefotaxime, and ceftazidime against Gram-negative bacteria. This may be due to the frequent use of prophylactic antibiotics, the severity of illness, and more extended hospital stays in surgical patients. In contrast, non-surgical wards showed higher resistance rates for tobramycin, piperacillin, ticarcillin/clavulanic acid, ceftriaxone, and nitrofurantoin, possibly due to chronic conditions and pre-existing resistance from outpatient antibiotic use. Similar patterns were observed for Gram-positive bacteria, with surgical wards demonstrating higher resistance rates for erythromycin, ciprofloxacin, ofloxacin, tetracycline, and clindamycin. On the other hand, non-surgical wards demonstrated higher resistance rates for norfloxacin, doxycycline, nitrofurantoin, and rifamycin.

Tigecycline and teicoplanin showed no resistance against Gram-positive and Gram-negative bacteria in both wards, underscoring their potential for treating MDR infections. Significant statistical differences in the resistance rates between wards to particular antibiotics, such as linezolid and erythromycin, highlight the need for additional research into the underlying mechanisms causing these variations. Our study observed a significantly higher overall MDR rate in Gram-negative bacteria (64.8%) than Gram-positive bacteria (43.5%). This aligns with numerous studies reporting a global rise in MDR among Gram-negative bacteria, attributed to their complex cell wall structure and the ease of acquiring resistance genes.[21,22]

The study identified significant variations in MDR rates among specific Gram-negative bacteria. *K. pneumoniae* showed the highest MDR rate (78.7%), followed by *P. aeruginosa* (77.2%) and *A. baumannii* (56.5%). *E. coli* displayed a lower but still concerning MDR rate of 60.0%. These findings are consistent with published research highlighting the emergence of MDR strains, particularly among *K. pneumoniae, A. baumannii*, and *P. aeruginosa*, posing significant challenges in healthcare settings.[18,23,24] Similar variations were observed for Gram-positive bacteria. *Enterococcus* spp. had the highest MDR rate (55.9%), followed by *S. aureus* (45.5%), *Streptococcus* spp. (37.0%), and *Streptococcus viridans* (23.6%). These results, by research indicating a rise in MDR Enterococcus and MRSA, emphasize the need for judicious use of antibiotics like macrolides and lincosamides, to which these bacteria often exhibit resistance.[25]

There are certain limitations to consider. The results may be more widely applicable if the patient population and geographic distribution for each bacterial grouping were disclosed. Studying the resistance mechanisms these drug-resistant microorganisms display could also provide more information for developing targeted treatments. Furthermore, the lack of data on catheterized patients is another limitation that could significantly affect the interpretation of AMR patterns. Future studies should incorporate this information for a more refined analysis.

Conclusions

This study sheds important light on the prevalence of UTIs pathogens and their AMR patterns in a teaching hospital in Vietnam. The findings reveal a significant burden of MDR pathogens, particularly *K. pneumoniae, P. aeruginosa, A. baumannii*, and *Enterococcus* spp. The high resistance rates to commonly used antibiotics underscore the urgent need to strengthen antimicrobial stewardship practices. Regular monitoring of resistance patterns is crucial to guide empirical therapy. Furthermore, the variations in resistance between surgical and non-surgical wards emphasize the importance of ward-specific infection control strategies. Future research should focus on identifying resistance mechanisms and expanding the geographic and population scope to develop more targeted and effective treatment protocols.

Ethical Information

The Military Hospital 103 ethics committee approved this study (Approval No. 35/CNChT- HĐĐĐ). The ethics committee waived the necessity for informed permission from participants due to the retroactive nature of the study. Before the examination, patient data was anonymized. The Declaration of Helsinki's guiding principles were followed in this investigation.

Acknowledgments

We would like to express our gratitude to the Military Hospital 103 staff members who have contributed to this study.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or in all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

There is no funding to report.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Stamm WE, Norrby SR. Urinary tract infections: disease panorama and challenges. *J Infect Dis*. 2001;183(Supplement_1):S1–S4. doi:10.1086/318850

2. Von Vietinghoff S, Shevchuk O, Dobrindt U, et al. The global burden of antimicrobial resistance - urinary tract infections. *Nephrol Dial Transplant*. 2024;39(4):581–588. doi:10.1093/ndt/gfad233
3. Urine Cultures. *Clinical Microbiology Procedures Handbook*. 2016:3.12.1–3.12.33.
4. N VA, Hoang LH, Le HHL, et al. Distribution and antibiotic resistance characteristics of bacteria isolated from blood culture in a teaching hospital in Vietnam during 2014-2021. *Infect Drug Resist*. 2023;16:1677–1692. doi:10.2147/idr.S402278
5. Mlugu EM, Mohamedi JA, Sangeda RZ, Mwambete KD. Prevalence of urinary tract infection and antimicrobial resistance patterns of uropathogens with biofilm forming capacity among outpatients in morogoro, Tanzania: a cross-sectional study. *BMC Infect Dis*. 2023;23(1):660. doi:10.1186/s12879-023-08641-x
6. Rosana Y, Ocviyanti D, Akbar W. Bacterial susceptibility patterns to cotrimoxazole in urinary tract infections of outpatients and inpatients in Jakarta, Indonesia. *Med J Indonesia*. 2020;29:316–321. doi:10.13181/mji.oa.204305
7. K S, B S, M S, Urooj A, K R. urinalysis as a predictor for urinary tract infection: an observational study. *Asian J Pharm Clin Res*. 2023;58–61. doi:10.22159/ajpcr.2023.v16i7.47557
8. Zagaglia C, Ammendolia MG, Maurizi L, Nicoletti M, Longhi C. Urinary tract infections caused by uropathogenic Escherichia *coli* strains-new strategies for an old pathogen. *Microorganisms*. 2022;10(7):1425. doi:10.3390/microorganisms10071425
9. Kraszewska Z, Skowron K, Kwiecińska-Piróg J, et al. Antibiotic resistance of enterococcus spp. isolated from the urine of patients hospitalized in the university hospital in North-Central Poland, 2016-2021. *Antibiotics*. 2022;11(12):1749. doi:10.3390/antibiotics11121749
10. Garcell HG, Al-Ajmi J, Arias AV, Abraham JC, Garmendia AMF, Hernandez TMF. Catheter-associated urinary tract infection and urinary catheter utilization ratio over 9 years, and the impact of the COVID-19 pandemic on the incidence of infection in medical and surgical wards in a single facility in Western Qatar. *Qatar Med J*. 2023;2023(1):14. doi:10.5339/qmj.2023.14
11. Khan H, Javeed M, Javed A, Farooq N. Prevalence and multidrug resistance pattern of E. Coli among urinary tract infection patients in tertiary care hospital of Multan. *J Bioresour Manag*. 2021;8:104–112. doi:10.35691/JBM.1202.0207
12. Chu CM, Lowder JL. Diagnosis and treatment of urinary tract infections across age groups. *Am J Clin Exp Obstet Gynecol*. 2018;219(1):40–51. doi:10.1016/j.ajog.2017.12.231
13. Magliano E, Grazioli V, Deflorio L, et al. Gender and age-dependent etiology of community-acquired urinary tract infections. *Sci World J*. 2012;2012:349597. doi:10.1100/2012/349597
14. Medina M, Castillo-Pino E. An introduction to the epidemiology and burden of urinary tract infections. *Ther Adv Urol*. 2019;11:1756287219832172. doi:10.1177/1756287219832172
15. Iskandar K, Molinier L, Hallit S, et al. Surveillance of antimicrobial resistance in low- and middle-income countries: a scattered picture. *Antimicrob Resist Infect Control*. 2021;10(1):63. doi:10.1186/s13756-021-00931-w
16. Khan A, Saraf VS, Siddiqui F, et al. Multidrug resistance among uropathogenic clonal group A E. Coli isolates from Pakistani women with uncomplicated urinary tract infections. *BMC Microbiol*. 2024;24(1):74. doi:10.1186/s12866-024-03221-8
17. Tan X, Pan Q, Mo C, et al. Carbapenems vs alternative antibiotics for the treatment of complicated urinary tract infection: a systematic review and network meta-analysis. *Medicine*. 2020;99(2):e18769. doi:10.1097/MD.0000000000018769
18. Miftode IL, Nastase EV, Miftode R, et al. Insights into multidrug-resistant K. pneumoniae urinary tract infections: from susceptibility to mortality. *Exp Ther Med*. 2021;22(4):1086. doi:10.3892/etm.2021.10520
19. Gajdács M, Ábrók M, Lázár A, Burián K. Increasing relevance of Gram-positive cocci in urinary tract infections: a 10-year analysis of their prevalence and resistance trends. *Sci Rep*. 2020;10(1):17658. doi:10.1038/s41598-020-74834-y
20. Naik B, Bhagyashree S, Shahana A, Veigas GJ, Scandashree K, Kumar R. A study on bacterial etiology and antibiotic utilization pattern among inpatient with urinary tract infections. *Indian J Pharm Pract*. 2023;16(2):125–130. doi:10.5530/ijopp.16.2.20
21. Silhavy TJ, Kahne D, Walker S. The bacterial cell envelope. *Cold Spring Harb Perspect Biol*. 2010;2(5):a000414. doi:10.1101/cshperspect.a000414
22. van Hoek AH, Mevius D, Guerra B, Mullany P, Roberts AP, Aarts HJ. Acquired antibiotic resistance genes: an overview. *Front Microbiol*. 2011;2:203. doi:10.3389/fmicb.2011.00203
23. Gomila A, Carratalà J, Eliakim-Raz N, et al. Risk factors and prognosis of complicated urinary tract infections caused by pseudomonas aeruginosa in hospitalized patients: a retrospective multicenter cohort study. *Infect Drug Resist*. 2018;11:2571–2581. doi:10.2147/idr.S185753
24. Bagińska N, Cieślik M, Górski A, Jończyk-Matysiak E. The role of antibiotic resistant A. baumannii in the pathogenesis of urinary tract infection and the potential of its treatment with the use of bacteriophage therapy. *Antibiotics*. 2021;10(3):281. doi:10.3390/antibiotics10030281
25. Brown NM, Goodman AL, Horner C, Jenkins A, Brown EM. Treatment of methicillin-resistant staphylococcus aureus (MRSA): updated guidelines from the UK. *JAC-Antimicrob Resist*. 2021;3(1):dlaa114. doi:10.1093/jacamr/dlaa114