El Ouweini AE, Don J, Alzuabi H, Levien T, Malaeb D. Assessment of vancomycin utilization in intensive care unit patients of a tertiary care hospital in the United Arab Emirates. Pharmacy Practice. 2024 Oct-Dec;22(4):2977.
https://doi.org/10.18549/PharmPract.2024.4.2977

Original Research

Assessment of vancomycin utilization in intensive care unit patients of a tertiary care hospital in the United Arab Emirates

Ahmad El Ouweini, Judit Don, Hadeel Alzuabi, Terri Levien, Diana Malaeb

Received (first version): 13-Sep-2023 Accepted: 09-Dec-2023 Published online: 15-Oct-2024

Abstract

Background: Adequate dosing and monitoring of vancomycin serum concentrations is necessary to maximize efficacy, minimize toxicity, and reduce the emergence of resistance. The aim of this study was to assess vancomycin dosing, administration and monitoring among adult and pediatric patients admitted to the intensive care unit. **Methods:** A retrospective, cohort study performed from October 2020 - October 2022 in a tertiary care hospital in the UAE. All patients received an IV vancomycin for a systemic bacterial infection. **Results:** Only 18.1% of the patients received loading doses. In 75.5% of the study population, vancomycin was started empirically. 55.4% of the patients had their trough levels measured, 61% of them had only 1 trough level measured, and the rest had more than 1 trough measured. Trough level was outside the target range in 50.6% of the patients. Obtaining the trough level before the 4th dose occurred in the majority (68.8%) of the patients. Nephrotoxicity occurred for 5.8% of the patients while receiving vancomycin. 61.2% of the patients did not have adequate renal function monitoring for patients who are on vancomycin. Total vancomycin appropriateness was achieved in only 16.7% of the patients which was mainly due to total trough inappropriateness. **Conclusion:** This study demonstrates a disparity in the proper utilization of vancomycin according to international guidelines within the included tertiary care hospital. It underscores the necessity for the development of dosing and monitoring protocols tailored to the utilization of vancomycin in these healthcare facilities.

Keywords: vancomycin; utilization; intensive care unit; monitoring; safety; efficacy

INTRODUCTION

Vancomycin is a glycopeptide antibiotic that has been in clinical use for over 50 years. It is one of the most widely used antibiotics in the treatment of serious gram-positive infections involving methicillin-resistant staphylococcus aureus (MRSA).[1] In 2017, an estimated 119,247 staphylococcus aureus bloodstream infections with 19,832 associated deaths occurred.[2] Initially almost exclusively health care–associated, by the mid-1990s, MRSA strains were reported as causing infections among previously healthy individuals in the community who lacked health care–associated risk factors.[3] As the cornerstone of treatment for MRSA infections, vancomycin use has increased with the increasing rates of MRSA.[4] Vancomycin demonstrates time-dependent killing of susceptible bacteria.[5] The first consensus guideline for therapeutic monitoring of vancomycin in adult patients was published in 2009, a consensus recommendations of the American Society of Health-System Pharmacists (ASHP), the Infectious Diseases Society of America (IDSA), and the Society Infectious Diseases Pharmacists (SIDP).[1] The primary recommendations consisted of eliminating routine monitoring of serum peak concentrations, emphasizing a ratio of area under the curve over 24 hours to minimum inhibitory concentration (AUC/MIC) of ≥400 as the primary PK/ PD predictor of vancomycin activity, and promoting serum trough concentrations of 15 to 20 mg/L as a surrogate marker for the optimal vancomycin AUC/MIC if the MIC was ≤1 mg/L in patients with normal renal function. The guideline also recommended, albeit with limited data support, that actual body weight be used to determine the vancomycin dosage and loading doses for severe infections in patients who were seriously ill.[1] Practically, trough serum vancomycin concentration is considered an accurate method for monitoring effectiveness. In order to achieve the therapeutic outcome, serum trough concentrations of 15–20 mg/L is needed in case of complicated infections as bacteremia, endocarditis, osteomyelitis, meningitis, hospital-acquired pneumonia and severe skin and soft tissue infection (e.g., necrotizing fasciitis) caused by Staphylococcus aureus.[1,7,8,9] This trough is recommended to improve penetration, increase the probability of obtaining optimal target serum concentrations, and improve clinical outcomes.[1] Trough levels should be obtained just prior to the next dose at steady-state conditions (just before the fourth dose). In addition, as the risk of resistance increases with the use of vancomycin a minimum serum trough concentrations above 10 mg/L should always be maintained to avoid its development.[1,7,8,9] Vancomycin dosages should be calculated based on ABW (actual body weight). For obese patients, initial dosing can be based on ABW and

Ahmad EL OUWEINI*. College of Pharmacy, Gulf Medical University, Ajman, United Arab Emirates. dr.ahmedelouweini@gmu.ac.ae
Judit DON. College of Pharmacy, Gulf Medical University, Ajman, United Arab Emirates. 2018ph15@mygmu.ac.ae
Hadeel ALZUABI. College of Pharmacy, Gulf Medical University, Ajman, United Arab Emirates. 2018ph13@mygmu.ac.ae
Terri LEVIEN. College of Pharmacy and Pharmaceutical Sciences, Washington State University, Pullman, WA, United States. levient@wsu.edu
Diana MALAEB. College of Pharmacy, Gulf Medical University, Ajman, United Arab Emirates. dr.diana@gmu.ac.ae

www.pharmacypractice.org (eISSN: 1886-3655 ISSN: 1885-642X)

then adjusted based on serum vancomycin concentrations to achieve therapeutic levels.[1,7] In most patients with normal renal function, vancomycin dosages of 15–20 mg/kg (based on ABW) given every 8–12 hours are required to achieve the suggested serum concentrations.[1,5,7,8,9] However, in order to achieve rapid attainment of this target concentration for seriously ill patients, a loading dose of 25–30 mg/kg (based on ABW) can be considered.[1,7,8,9] Vancomycin's adverse effects mostly are unrelated to serum drug concentration and include fever, chills, and phlebitis.[10] Other side effect is red man syndrome that may be associated with histamine release and manifests as tingling and flushing of the face, neck, and upper torso. It is most likely to occur when larger dosages are infused too rapidly (>500 mg over ≤30 minutes).[10] To minimize infusion-related adverse effects, vancomycin should be administered intravenously over an infusion period of at least 1 hour, and in case of higher dosages (e.g., 2 g), the infusion time should be extended to 2 hours.[1,7] Vancomycin has long been considered a nephrotoxic and ototoxic agent.[1] Nonetheless, there is limited data suggesting a direct causal relationship between toxicity and specific serum vancomycin concentrations.[1,7] Hence, monitoring trough serum concentrations to reduce nephrotoxicity is best suited for aggressive dosing (trough levels 15-20 mg/L) and recommended for patients with unstable renal function and those receiving prolonged courses of therapy (more than 5 days).[1,7,9] In contrast, frequent monitoring (more than one trough before the fourth dose) for short course or lower intensity dosing (to attain target trough concentrations below 15 mg/L) is not recommended.[1,7,9] There are limited data to support the safety of troughs 15-20 mg/L.[1,7,9] One study highlighted that the interest in evaluating the relationship between vancomycin trough concentrations and incidence of nephrotoxicity renewed with increasing reports of vancomycin-induced nephrotoxicity at a trough, of 15-to 20-mg/L.[11] Also, other results suggest that aggressive vancomycin dosing and prolonged vancomycin administration may be associated with a greater risk for renal toxicity in patients with MRSA health care–associated pneumonia (HCAP).[12] Based on a retrospective study, "Prescribing Habits of Vancomycin in the Emergency Department: Are We Dosing Appropriately?", 19.6% of patients received an appropriate dose based on the ASHP, SIDP, and IDSA recommendations in the Emergency Department that was within the recommended dosing range of 15–20 mg/kg based on actual body weight.[13,5] In summary, adequate dosing and monitoring of serum concentrations is necessary to maximize efficacy, minimize toxicity, and reduce the emergence of resistance.[14] Considering the lack of information assessing the utilization of vancomycin in ICUs of hospitals across the UAE, there is a strong need to assess the current practice in order to pave the way to reach the standard vancomycin utilization guidelines. The aim of this study was to assess vancomycin dosing, administration and monitoring among adult and pediatric patients admitted to the ICU.

MATERIALS AND METHODS

Study Design

Retrospective, cohort study performed from October 2020 - October 2022 in a tertiary care hospital in the UAE. This study was approved by the Institutional Review Board. Eligible patient medical charts were reviewed from the ICU-admitted patients, and information were collected using a data collection sheet. Eligibility criteria included neonates, pediatric and adult patients who received an IV vancomycin for a systemic bacterial infection. Excluded patients were those receiving vancomycin for local Clostridium difficile infection and for procedural prophylaxis.

Sample size calculation

Using the G-power software, a minimum sample of 163 was deemed necessary, based on a R^2 deviation of 5%, an alpha error of 5%, a power of 80% and a maximum of 23 variables to be entered in the final model.

Data collection and variables

A data collection sheet was created to study the variables that were important to assess the appropriate use of vancomycin based on the updated recommendations of the ASHP, IDSA, and SIDP, in 2020. The data collection sheet was content-validated by a panel of experts including PharmD professors. Data collection was performed by a registered clinical pharmacist and last year PharmD students through the identification of patients from medical records who received IV vancomycin for systemic bacterial infections. The data collection sheet retrieved information regarding the demographic characteristics of the patients, the type of bacterial infection, information loading and maintenance dosing and administration, trough and kidney function monitoring, and empiric and/or targeted vancomycin therapy approach. Total vancomycin appropriateness was calculated based on the appropriateness of the following variables combined: loading dose choice and dose, maintenance dose, trough level appropriateness, vancomycin administration appropriateness, empiric dosing appropriateness and targeted therapy appropriateness.

Statistical analysis

IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, N.Y., USA) was used to perform the data analysis. Dichotomous and categorical variables were presented as percentages, and the continuous variables were displayed as mean±standard deviation (SD). Mean values, standard deviations, and frequencies were computed to illustrate current prescribing practices of vancomycin in the neonatal, pediatric, and adult intensive care units in this tertiary care hospital. All factors that showed significance in the bivariate analysis were entered as independent variable. $P < 0.05$ was deemed statistically significant in the final model.

RESULTS

A total of 138 patients was included in this study. Table 1 provides a summary of the patients' demographic statistics, including gender, age, BMI, CrCl, and vancomycin indications. This study included neonates, pediatric, and adult patients with

Table 1. Sociodemographic Characteristics of Enrolled Patients	
Age, years, mean ± SD	24.79 ± 29.52
Age categories, no. (%) • Newborn - 18 years • 18 – 64.9 years • 65 years and above	 77 (55.8) 41 (29.7) 20 (14.5)
Gender, no. (%) • Male • Female	 62 (44.9) 76 (55.1)
BMI, mean ± SD	26.41 ± 5.15
BMI Categories • Under-weight <18.5 • Normal weight 18.5-24.9 • Over-weight 25-29.9 • Obesity >30	 2 (3.2) 25 (40.3) 23 (37.1) 12 (19.4)
Creatinine Clearance, mL/min, mean ± SD	96.75 ± 47.84
Vancomycin Indications, no. (%) Sepsis Pneumonia SSTI Meningitis UTI	 84 (60.9) 16 (11.6) 24 (17.4) 7 (5.1) 7 (5.1)

a higher percentage for neonates and pediatrics. The majority of the study population had normal to overweight BMI. Most of the vancomycin doses given were for sepsis/septic shock.

As shown in table 2 below, loading doses were indicated for 77.5% of the patients despite the fact that only 18.1% of them received loading doses. Majority of the study population (92%) received maintenance doses based on their actual body weight. All of the patients received vancomycin doses over 1 hour for each 1 gram administered. In 75.5% of the study population, vancomycin was started empirically.

Table 2. Vancomycin Dosing Regimen and Administration Patterns	
	No. (%)
Loading dose is indicated	107 (77.5)
Loading dose is given	25 (18.1)
Maintenance dose based on ABW	127 (92.0)
Intermittent infusion time (each 1 gm for at least 60 minutes)	138 (100.0)
Empiric therapy	105 (75.5)

Table 3 below shows the monitoring patterns for the efficacy and safety of vancomycin among critically ill patients. As shown in Table 3, 55.4% of the patients had their trough levels measured, 61% of them had only 1 trough level measured, and the rest had more than 1 trough measured. Obtaining the trough level before the 4th dose occurred in the majority (68.8%) of the patients. Nephrotoxicity occurred for 5.8% of the patients while taking vancomycin. The majority of the patients were also taking concomitantly other nephrotoxic medications such as NSAIDs, aminoglycosides, and amphotericin B. 61.2% of the patients did not have adequate renal function monitoring for patients who are on vancomycin (i.e. requesting two or more consecutive SCr readings present).

Table 3. Vancomycin Trough and Kidney Function Monitoring Patterns	
	No. (%)
Trough concentration measured	77 (55.4)
One trough obtained	47 (61.0)
Multiple troughs obtained	30 (39.0)
Trough obtained before 4th dose	53 (68.8)
Trough obtained • Before 3rd dose • Before 5th dose • Before 6th dose • Before 8th dose	 23 (16.5) 2 (1.4) 1 (0.7) 3 (2.2)
A need for dose change based on trough level	40 (51.9)
An increase in serum creatinine by 0.3 mg/dl from the baselines in 48 hours or in 7 days	8 (5.8)
Two or more consecutive SCr readings present	54 (38.8)
Presence of nephrotoxic medications • Aminoglycosides • NSAIDs • Amphotericin B	98 (70.5) 73 (74.5) 22 (22.4) 3 (3.1)

Total vancomycin appropriateness was achieved if all of the following variables were met: appropriate loading dose, appropriate maintenance dose according to indication, appropriate IV administration duration, total trough level appropriateness (appropriate trough level, appropriate number of trough measurements, and appropriate dose change based on trough level), and appropriate empiric choice of vancomycin.

Bivariate analysis

Female gender was significantly associated with an appropriate loading dose (Table 5). Patients who were in the age category of newborn - 18 years were significantly associated with a higher appropriate maintenance dose according to indication. Adult patients as well as having pneumonia and meningitis were significantly associated with a higher total trough appropriateness. Adult patients were significantly associated with a higher total vancomycin appropriateness.

Table 4. Vancomycin Total Appropriateness	
No. (%)	
Loading Dose Appropriate • No • Yes	 9 (36.0) 16 (64.0)
Maintenance Dose Appropriate According to Indication • No • Yes	 18 (13.0) 120 (87.0)
• **Appropriate Vancomycin IV administration duration**	138 (100.0)
Trough level appropriate • No • Yes	 39 (50.6) 38 (49.4)
Number of trough measurements appropriate • No • Yes	 21 (27.3) 56 (72.7)
Appropriate dose change based on trough level • No • Yes	 56 (72.7) 21 (27.3)

Total trough appropriateness	
• No	108 (78.3)
• Yes	30 (21.4)
Appropriate empiric choice of Vancomycin	
• No	38 (27.5)
• Yes	100 (72.5)
Total Appropriateness	
• No	115 (83.3)
• Yes	23 (16.7)

Table 5. Bivariate Analysis of factors associated with vancomycin appropriateness

Variables	**Appropriate Loading Dose, no. (%)**		**P- value**
	No	**Yes**	
Gender			
Male	8 (57.1)	6 (42.9)	**0.033**
Female	1 (9.1)	10 (90.9)	
Age categories			
18 – 64.9 years	4 (33.3)	8 (66.7)	1.000
65 years and above	5 (38.5)	8 (61.5)	
Indications			
Sepsis	4 (33.3)	8 (66.7)	
Pneumonia	2 (40)	3 (60)	0.900
SSTI	2 (50)	2 (50)	
UTI	1 (25)	3 (75)	
Variables	**Appropriate Maintenance Dose According to Indication, no. (%)**		**P- value**
	No	**Yes**	
Gender			
Male	9 (11.8)	67 (88.2)	0.800
Female	9 (14.5)	53 (85.5)	
Age categories			
Newborn - 18 years	6 (7.8)	71 (92.2)	**0.030**
18 – 64.9 years	6 (14.6)	35 (85.4)	
65 years and above	6 (30)	14 (70)	
Indications			
Sepsis	11 (13.1)	73 (86.9)	
Pneumonia	3 (18.8)	13 (81.3)	0.483
SSTI	2 (8.3)	22 (91.7)	
Meningitis	0 (0)	7 (100)	
UTI	2 (28.6)	5 (71.4)	
Variables	**Maintenance Dose Based on ABW, no. (%)**		**P- value**
	No	**Yes**	
Gender			
Male	7 (9.2)	69 (90.8)	0.394
Female	4 (6.5)	58 (93.5)	
Age categories			
Newborn - 18 years	4 (5.2)	73 (94.8)	0.092
18 – 64.9 years	3 (7.3)	38 (92.7)	
65 years and above	4 (20)	16 (80)	
Indications			
Sepsis	8 (9.5)	76 (90.5)	0.435
Pneumonia	2 (12.5)	14 (87.5)	
SSTI	0 (0)	24 (100)	
Meningitis	0 (0)	7 (100)	
UTI	1 (14.3)	6 (85.7)	
Variables	**Total Trough Appropriateness, no. (%)**		**P- value**
	No	**Yes**	
Gender			
Male	60 (78.9)	16 (21.1)	0.839
Female	48 (77.4)	14 (22.6)	
Age categories			
Newborn - 18 years	51 (66.2)	26 (33.8)	**0.001**
18 – 64.9 years	39 (95.1)	2 (4.9)	
65 years and above	18 (90)	2 (10)	
Indications			
Sepsis	59 (70.2)	25 (29.8)	**0.027**
Pneumonia	16 (100)	0 (0)	
SSTI	21 (87.5)	3 (12.5)	
Meningitis	7 (100)	0 (0)	
UTI	5 (71.4)	2 (28.6)	
Variables	**Empiric Choice Appropriate According to Guidelines, no. (%)**		**P- value**
	No	**Yes**	
Gender			
Male	24 (31.6)	52 (68.4)	0.162
Female	14 (22.6)	48 (77.4)	
Age categories			
Newborn - 18 years	17 (22.1)	60 (77.9)	0.140
18 – 64.9 years	16 (39)	25 (61)	
65 years and above	5 (25)	15 (75)	
Indications			
Sepsis	22 (26.2)	62 (73.8)	0.665
Pneumonia	6 (37.5)	10 (62.5)	
SSTI	6 (25)	18 (75)	
Meningitis	1 (14.3)	6 (85.7)	
UTI	3 (42.9)	4 (57.1)	
Variables	**Total Appropriateness, no. (%)**		**P- value**
	No	**Yes**	
Gender			
Male	64 (84.2)	12 (15.8)	0.821
Female	51 (82.3)	11 (17.7)	
Age categories			
Newborn - 18 years	58 (75.3)	19 (24.7)	**0.016**
18 – 64.9 years	39 (95.1)	2 (4.9)	
65 years and above	18 (90)	2 (10)	
Indications			
Sepsis	65 (77.4)	19 (22.6)	0.070
Pneumonia	16 (100)	0 (0)	
SSTI	22 (91.7)	2 (8.3)	
Meningitis	7 (100)	0 (0)	
UTI	5 (71.4)	2 (28.6)	

Numbers in bold indicate significant *p* values

DISCUSSION

The most effective antibacterial for treating MRSA infections has been vancomycin for decades. However, as a result of improper utilization and monitoring, clinical results have worsened and failure rates have gone up.[15] The goal of this study was to assess vancomycin dosing, administration and monitoring among adult and pediatric patients admitted to the ICU. To the authors' knowledge, this was the first study conducted in the UAE that assessed vancomycin utilization patterns in the intensive care units of a tertiary care hospital.

Loading doses are not typically indicated for neonates or pediatric populations who receive vancomycin as an intermittent dosing regimen. On the other hand, for children who receive it as a continuous infusion, loading doses have been suggested.[16] In this study, only an intermittent dosing regimen was used for vancomycin administration. Hence, no loading dose was neither indicated nor given for the pediatric population of this study. Therefore, this explains the low percentage of patients who received loading doses across the overall study population.

Vancomycin weight-based dosing depends on actual body weight.[16] In this study, there was high compliance with proper vancomycin dosing according to ABW. Additionally, this study revealed that the nursing practice for vancomycin intermittent infusion is appropriate in this hospital since all of the patients received vancomycin doses over 1 hour for each 1 gram administered. This slow infusion rate significantly reduces the incidence of Redman syndrome.[17]

Notably, 75.5% of the infected patients were started empirically on vancomycin. These outcomes are similar to other trials, when 66.3% of cases began empiric treatment because of suspected infection.[18]

This study highlights that trough vancomycin levels were not measured in around 45% of the patients. For those patients with measured trough levels, more than 50% had trough levels that were outside the therapeutic range. In a study conducted in 2014 in Malaysia, serum vancomycin trough levels were monitored in 67% of the patients and for only 22.8% trough levels were found to be within the therapeutic range.[19] In this study, more than one trough levels were measured in only 39% of the patients, although as mentioned earlier, more than 50% of patients did not have the appropriate trough levels in their first obtained level. This reflects the inadequacy of trough level monitoring in this patient population.

Most of the patients (68.8%) whose vancomycin trough levels were monitored, had their trough concentrations measured before the 4th dose as indicated in the vancomycin therapeutic guidelines.[7] Measuring vancomycin levels earlier than this timing shows vancomycin serum levels before reaching the steady state concentration which results in suboptimal clinical decisions and outcomes. Similarly, taking vancomycin serum levels after the 4th dose (e.g. before 5th or 6th) will result in longer than needed time to make the necessary dose adjustments and hence overall patient outcomes.[20]

In a study conducted by Traugott et al, the majority of inappropriate vancomycin trough levels were due to improper timing of sample collections (55%).[21] Such results provoke a need for the standardization of the proper timing and number of vancomycin trough concentration measurements. The inadequate monitoring of vancomycin can be linked to the lack of interdisciplinary approaches in this hospital and other similar hospitals as well as the insufficient input from clinical pharmacists when prescribing.

Nephrotoxicity is among the significant adverse effects associated with the use of vancomycin. It is usually reversible and may result in acute kidney injury, predominantly occurring in patients with multiple risk factors (e.g. duration of therapy > 7 days, obesity, preexisting kidney dysfunction, concomitant nephrotoxic medications).[2]Nephrotoxicity occurred in 5.8% of the patients while taking vancomycin. The majority of the patients were also taking concomitantly other nephrotoxic medications such as NSAIDs, aminoglycosides, and amphotericin B. Hence, the authors could not link the nephrotoxicity to vancomycin, to other nephrotoxic medications or to other factors. This study showed that the majority of the patients did not have adequate renal function monitoring for patients who are on vancomycin (i.e. requesting two or more consecutive serum creatinine readings).

Total vancomycin appropriateness was achieved in only 16.7% of the patients which was mainly due to total trough inappropriateness. According to this study results, the younger the patients are, the more significantly it is associated with appropriate maintenance dose according to indication. This can be because a specified hospital routine is being followed. On the other hand, the older the patients are, the more likelihood that it will be significantly associated with total vancomycin appropriateness.

LIMITATIONS

This research has a number of limitations. To begin with, the small sample size could diminish the significance of the findings. Another drawback involves the data collection being limited to just one hospital, which constrains the generalizability of the findings to other hospitals in other emirates. Furthermore, the retrospective study design posed a limitation by restricting prospective interactions with patients and raising the rate of missing data and accuracy of collected data. An example of this is that the paper does not establish any link between vancomycin trough levels and outcomes, whether in terms of effectiveness or safety. In fact, the study team lacked access to this data because it was a retrospective study, and not all the necessary information had been documented. Another significant limitation to consider is that achieving the most precise target for vancomycin therapy involves reaching an area under the curve to minimum inhibitory concentration (AUC/MIC) ratio of ≥400. However, in this study, the authors relied on trough serum concentrations as a predictor for AUC/MIC. This research aims to evaluate how well vancomycin is utilized clinically in accordance with established guidelines. As such, it serves as an initial assessment of the prevailing clinical practices and represents a starting point for improving adherence to these guidelines.

CONCLUSION

In conclusion, vancomycin remains a cornerstone in the management of serious, drug-resistant infections. Vancomycin proper utilization in practice requires an interdisciplinary team that effectively employs all available resources to optimize adherence to the internationally accepted vancomycin dosing and monitoring guidelines. This includes proper selection of

empiric and targeted therapy, accurate weight-based dosing, and adequate monitoring of trough levels, AUC/MIC and renal function on routine basis while the patient is on vancomycin therapy. This study shows notable difficulties in the utilization of vancomycin, posing a direct risk of treatment ineffectiveness and diminished antibiotic efficacy. It contributes to existing literature by highlighting the deviation of clinicians from the international guidelines related to vancomycin usage, dosing, and monitoring. Therefore, it is advisable to educate healthcare providers on the correct dosing of vancomycin, with a focus on attaining therapeutic trough levels within the target range, and to promote adherence to the latest consensus guidelines. Additionally, the establishment of dosing and monitoring protocols within individual hospitals is of paramount importance.

DECLARATIONS

Ethical statement

The study was approved by the Institutional Review Board of Gulf Medical University (Ref: IRB/COP/FAC/74/DEC-2022).

DATA AVAILABILITY STATEMENT

The database cannot be shared publicly but is available upon a reasonable request from the corresponding author.

DECLARATION OF INTERESTS

The authors declare no conflict of interest.

FUNDING

This research received no external funding.

AUTHOR CONTRIBUTIONS

Conceptualization, A.E.O.; methodology, A.E.O.; validation, A.E.O., D.M. and T.L.; formal analysis, A.E.O., D.M. and T.L.; investigation, A.E.O., D.M.; resources, T.L..; data curation, A.E.O, J.D., H.A.Z.; writing—original draft preparation, A.E.O, J.D., H.A.Z.; writing—review and editing, D.M., T.L.; visualization, A.E.O, D.M.; supervision, D.M.; project administration, A.E.O., D.M. and T.L.; funding acquisition. All authors have read and agreed to the published version of the manuscript.

ACKNOWLEDGMENTS

None.

ABBREVIATIONS

Methicillin-resistant staphylococcus aureus (MRSA), Intensive Care Unit (ICU), Area under the curve over 24 hours to minimum inhibitory concentration (AUC/MIC), Actual body weight (ABW), Health care–associated pneumonia (HCAP), American Society of Health-System Pharmacists (ASHP), Society of Infectious Diseases Pharmacists (SIDP), and Infectious Diseases Society of America (IDSA), Statistical Package for the Social Sciences (SPSS), SD, Standard deviation.

References

1. Rybak MJ, Le J, Lodise TP, et al. Therapeutic monitoring of vancomycin for serious methicillin-resistantstaphylococcus aureusinfections: A revised consensus guideline and review by the American Society of health-system pharmacists, the Infectious Diseases Society of America, the Pediatric Infectious Diseases Society, and the Society of Infectious Diseases Pharmacists. American Journal of Health-System Pharmacy. 2020;77(11):835-64.
2. Vital signs: Epidemiology and recent trends in Methicillin-resistant and in methicillin-susceptible Staphylococcus aureus bloodstream infections - united states. Centers for Disease Control and Prevention. https://www.cdc.gov/mmwr/volumes/68/wr/mm6809e1.htm. Published March 7, 2019. Accessed December 10, 2022.
3. Herold BC, Immergluck LC, Maranan MC, et al. Community-acquired methicillin-resistant Staphylococcus aureus in children with no identified predisposing risk. JAMA 1998; 279:593-8. https://doi.org/10.1001/jama.279.8.593
4. Vazin A, Mahi Birjand M, Darake M. Evaluation of vancomycin therapy in the adult icus of a teaching hospital in Southern Iran. Drug, Healthcare and Patient Safety. 2018;10:21-6. https://doi.org/10.2147/dhps.s149451
5. Rosini JM, Grovola MR, Levine BJ,et al. Prescribing habits of vancomycin in the Emergency Department: are we dosing appropriately.J Emerg Med. 2013;44(5):979-84. https://doi.org/10.1016/j.jemermed.2012.11.051
6. Ryback MJ.The pharmacokinetic and pharmacodynamics properties of vancomycin. Clin Infec Dis 2006;42(suppl):S35-9. https://doi.org/10.1086/491712
7. Rybak M,Lomaestro B , Rotschafer JC et al. Vancomycin Therapeutic Guidelines: A Summary of Consensus Recommendations from the Infectious Diseases Society of America, the American Society of Health-System Pharmacists, and the Society of Infectious Diseases Pharmacists.Clin Infect Dis 2009;49:325-7. https://doi.org/10.1086/600877
8. Liu C, Bayer A , Cosgrove SE, et al. Clinical practice guideline by the Infectious Disease Society of America for the treatment of methicillin- resistant staphylococcus aureus infections in adults and children. Clin Infect Dis 2011;52:e18-55. https://doi.org/10.1093/cid/ciq146
9. John C ROtshafer .Vancomycin and new agents for MRSA infections.

10. Ghasemiyeh P, Vazin A, Zand F, et al. Pharmacokinetic assessment of vancomycin in critically ill patients and nephrotoxicity prediction using individualized pharmacokinetic parameters. Frontiers in Pharmacology. 2022;13:912202. https://doi.org/10.3389/fphar.2022.912202
11. Van Hal SJ, Paterson DL, Lodise TP. Systematic review and meta-analysis of vancomycin-induced nephrotoxicity associated with dosing schedules that maintain troughs between 15 and 20 milligrams per liter. Antimicrob Agents Chemother. 2013;57(2):734-44. https://doi.org/10.1128/aac.01568-12
12. Jeffres MN, Isakow W, Doherty JA, et al. A retrospective analysis of possible renal toxicity associated with vancomycin in patients with health care-associated methicillin-resistant Staphylococcus aureus pneumonia. Clin Ther. 2007;29(6):1107-15. https://doi.org/10.1016/j.clinthera.2007.06.014
13. Sirard S, Abou Chakra CN, Langlois MF, Perron J, Carignan A, Valiquette L. Is Antimicrobial Dosing Adjustment Associated with Better Outcomes in Patients with Severe Obesity and Bloodstream Infections? An Exploratory Study. Antibiotics (Basel). 2020;9(10):707. https://doi.org/10.3390/antibiotics9100707
14. Kollef MH Limitations of vancomycin in the management of resistant staphylococcal infections. Clin Infect Dis. 2007;45(3):S191-5. https://doi.org/10.1086/519470
15. Malaeb DN, Fahs IM, Salameh P, Hallit S, Saad M, Bourji J, et al. Assessment of vancomycin utilization among Lebanese hospitals. Saudi Med J. 2019;40(2):152-7. https://doi.org/10.15537/smj.2019.2.23872
16. Moise PA, Schentag JJ. Vancomycin treatment failures in Staphylococcus aureus lower respiratory tract infections. Int J Antimicrob Agents. 2000;16(1):S31-4. https://doi.org/10.1016/s0924-8579(00)00303-4
17. Pacifici GM, Allegaert K. Clinical pharmacokinetics of vancomycin in the neonate: a review. Clinics (Sao Paulo). 2012;67(7):831-7. https://doi.org/10.6061/clinics/2012(07)21
18. Blot S, Koulenti D, Akova M, Bassetti M, De Waele JJ, Dimopoulos G, et al. Does contemporary vancomycin dosing achieve therapeutic targets in a heterogeneous clinical cohort of critically ill patients? Data from the multinational DALI study. Crit Care. 2014;18(3):R99. https://doi.org/10.1186/cc13874
19. Sivagnanam S, Deleu D. Red man syndrome. Crit Care. 2003;7(2):119-20. https://doi.org/10.1186/cc1871
20. Bakke V, Sporsem H, Von der Lippe E, Nordøy I, Lao Y, Nyrerød HC et al. Vancomycin levels are frequently subtherapeutic in critically ill patients: a prospective observational study. Acta Anaesthesiol Scand. 2017;61(6):627-35. https://doi.org/10.1111/aas.12897
21. Islahudin F, Ong HY. Appropriate vancomycin use in a Malaysian tertiary hospital based on current HICPAC recommendations. J Infect Dev Ctries. 2014;8(10):1267-71. https://doi.org/10.3855/jidc.4676
22. Kacířová I, Grundmann M. Terapeutické monitorování vankomycinu v rutinní klinické praxi [Therapeutic monitoring of vancomycin in routine clinical practice]. Vnitr Lek. 2014;60(10):846-51.
23. Traugott KA, Maxwell PR, Green K, Frei C, Lewis JS 2nd. Effects of therapeutic drug monitoring criteria in a computerized prescriber-order-entry system on the appropriateness of vancomycin level orders. Am J Health Syst Pharm. 2011;68(4):347-52. https://doi.org/10.2146/ajhp090661
24. Arnaud FCS, Libório AB. Attributable nephrotoxicity of vancomycin in critically ill patients: a marginal structural model study. J Antimicrob Chemother. 2020;75(4):1031-7. https://doi.org/10.1093/jac/dkz520