ARTICLE

Safe and effective use of vancomycin

Amy Legg
Clinical Pharmacist[1]
PhD candidate[2]

Felicia Devchand
Senior Editor[3]

Amanda Gwee
Infectious Diseases Physician, Clinical Pharmacologist and General Paediatrician[4]
Group Leader[5]
Associate Professor[6]

Indy Sandaradura
Clinical Microbiologist and Infectious Diseases Physician[7]
Clinical Senior Lecturer[8]

Tony Lai
Senior Pharmacist, Antimicrobial Stewardship[9]
Honorary Clinical Lecturer[8]

[1] Royal Brisbane and Women's Hospital
[2] Menzies School of Health Research, Charles Darwin University
[3] Therapeutic Guidelines Limited
[4] The Royal Children's Hospital Melbourne
[5] Antimicrobials Research Group, Murdoch Children's Research Institute, Melbourne
[6] Department of Paediatrics, The University of Melbourne
[7] Centre for Infectious Diseases and Microbiology, Westmead Hospital, Sydney
[8] The University of Sydney
[9] The Children's Hospital at Westmead, Sydney

Keywords
pharmacodynamics, pharmacokinetics, therapeutic drug monitoring, vancomycin

Aust Prescr 2025;48:54–9
https://doi.org/10.18773/austprescr.2025.013

SUMMARY

Vancomycin is an important antimicrobial for prophylactic, empirical and directed therapy of Gram-positive organisms.

Therapeutic drug monitoring is recommended for all patients expected to receive vancomycin for more than 48 hours to optimise drug exposure. Monitoring the area under the concentration–time curve over a 24-hour period (AUC_{24}) for vancomycin is preferred over monitoring trough plasma concentrations. An AUC_{24} of 400 to 600 mg.hr/L is recommended for infections other than central nervous system infections.

Vancomycin may cause nephrotoxicity, ototoxicity, cutaneous reactions, hypersensitivity and haematological toxicity. Reducing the incidence of vancomycin-induced nephrotoxicity involves recognising and modifying risk factors where possible.

Introduction

Vancomycin is an important antimicrobial for prophylactic, empirical and directed therapy of Gram-positive pathogens. The use of vancomycin requires therapeutic drug monitoring to balance efficacy and toxicity.

Historically, trough plasma concentrations have been used for vancomycin therapeutic drug monitoring. Many guidelines now recommend monitoring the area under the concentration–time curve over a 24-hour period (AUC_{24}) in most patients.

This article highlights important considerations around vancomycin use, including appropriate therapeutic targets and the use of AUC_{24}-based monitoring compared with trough-based monitoring. The article also discusses the implementation of AUC_{24}-based monitoring into clinical practice, and considerations in young infants and children.

Targets for vancomycin efficacy and toxicity

The pharmacokinetic/pharmacodynamic target that best predicts vancomycin efficacy is the area under the concentration–time curve over a 24-hour period to minimum inhibitory concentration (AUC_{24}/MIC) ratio. If AUC_{24} monitoring is unavailable, trough-based targets can be used (discussed in 'Vancomycin monitoring and dosage adjustment' section).

Targets for efficacy

Data for vancomycin AUC_{24}/MIC efficacy targets relate primarily to infections caused by *Staphylococcus aureus*. For methicillin-resistant *S. aureus* (MRSA), multiple in vitro and in vivo studies suggest that an AUC_{24}/MIC ratio of 400 mg.hr/L or more is an appropriate target for clinical effectiveness.[1] Targets for other pathogens have been reported. For coagulase-negative staphylococci, an AUC (over the first 24 hours) of 300 mg.hr/L or above was associated with a 7.3-fold increase in bacteriological cure.[2] For enterococcal bacteraemia, an AUC_{24}/MIC target of 389 mg.hr/L or more was associated with reduced mortality.[3]

Data are lacking to inform an appropriate serum AUC_{24}/MIC target for central nervous system (CNS) infections, where reduced penetration to the site of infection has previously resulted in higher trough concentration targets being recommended than for bloodstream infections.

Targets for toxicity

Vancomycin-induced nephrotoxicity is the result of drug accumulation in proximal tubular cells causing acute tubular necrosis, acute interstitial nephritis and tubular cast formation.[4,5] The risk of vancomycin-induced nephrotoxicity increases with increasing drug exposure (Figure 1); however, there is no 'safe' zone where the drug is devoid of risk. Using all available studies, an AUC_{24} exceeding 600 mg.hr/L, or a trough concentration above 15 mg/L (which likely indicates a supratherapeutic AUC_{24}), increases the risk of nephrotoxicity compared with lower exposures.[6-8] Although trough concentrations have been linked to acute kidney injury (AKI) in many retrospective studies, animal models suggest that the AUC_{24} or peak vancomycin concentrations are more closely correlated with AKI.[9] When patients experience AKI while receiving vancomycin, drug concentrations will increase because clearance is reduced, regardless of whether vancomycin was the cause.

Other vancomycin toxicities are unlikely to be dose or concentration dependent. Vancomycin infusion reactions can occur and are related to the rate of vancomycin administration. Limiting the vancomycin infusion rate to 10 mg/minute or below can reduce the risk of an infusion-related reaction. Other vancomycin hypersensitivity reactions can occur (e.g. anaphylaxis, severe cutaneous adverse reactions), although a definite relationship between vancomycin exposure and toxicity remains unclear.[10] Neutropenia is associated with prolonged durations of vancomycin use.[11,12] Ototoxicity, which is rare, has not been reliably shown to be associated with vancomycin exposure.

Minimum inhibitory concentration determination

The MIC of the pathogen is the denominator in the AUC_{24}/MIC ratio; however, there are challenges with using MICs in clinical practice. Individual vancomycin MICs are often not reported for every clinical isolate and MIC determination methods differ between sites. Although there can be discrepancies in the MIC obtained with different methods, the AUC_{24}/MIC target should not be altered based on the MIC determination method.[13]

To simplify practice, an MIC of 1 mg/L may be assumed for vancomycin-susceptible pathogens in AUC_{24}/MIC calculations. Although the European Committee on Antimicrobial Susceptibility Testing breakpoint for *S. aureus* includes an MIC of up to and including 2 mg/L,[14] if an MIC of 2 mg/L is used in the pharmacokinetic/pharmacodynamic calculation, the AUC_{24} target becomes 800 mg.hr/L, which carries an unacceptable risk of toxicity.

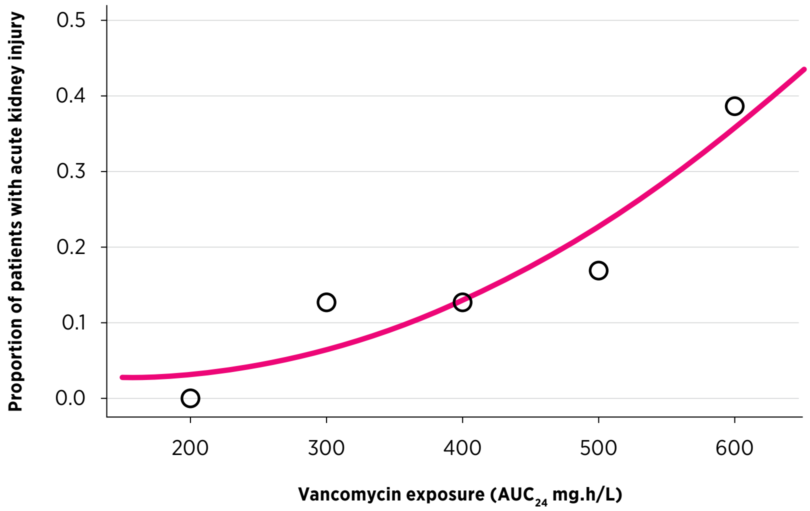
Controversy remains about the use of vancomycin for isolates with an MIC above 1 mg/L, and some guidelines recommend considering an alternative antimicrobial in this situation.[1]

Vancomycin monitoring and dosage adjustment

To optimise drug exposure and minimise toxicity, therapeutic drug monitoring is recommended for all patients expected to receive vancomycin for more than 48 hours. Therapeutic drug monitoring includes dose individualisation (i.e. dose modification) to ensure a patient achieves target drug exposure.

The recommended vancomycin drug exposure is an AUC_{24} of 400 to 600 mg.hr/L for infections other than CNS infections. Traditionally, vancomycin trough plasma concentrations of 15 to 20 mg/L have been recommended because of the high mortality from MRSA bacteraemia and an underappreciation of the risk of AKI at these exposures. However, trough concentrations of 15 to 20 mg/L often result in an AUC_{24} exceeding 600 mg.hr/L (especially if using 12-hourly vancomycin dosing). Additionally, trough concentrations do not reliably predict the AUC_{24}.[15,16]

Figure 1 Correlation between vancomycin exposure and acute kidney injury[6]



AUC_{24} = area under the concentration–time curve over a 24-hour period
Figure adapted from reference 6

Most patients with a trough concentration of 10 to 15 mg/L and who are not critically unwell will achieve an AUC_{24} greater than 400 mg.hr/L, making this trough concentration range a reasonable alternative to AUC_{24}-based monitoring if unavailable.[17]

Pre-dialysis concentrations between 16 and 20 mg/L are recommended for patients receiving haemodialysis to achieve a target AUC_{24} of 400 to 600 mg.h/L.[18] AUC_{24}-based monitoring may not be possible in patients with rapidly changing kidney function, where redosing can occur as vancomycin trough concentrations fall below 15 or 20 mg/L.[19]

Methods of AUC_{24} monitoring

The use of AUC_{24} monitoring has increased with freely available dosing software programs that calculate the AUC_{24} and provide dosing recommendations using one or two vancomycin concentrations. This monitoring method has resulted in lower vancomycin daily doses, lower trough concentrations and decreased rates of AKI without compromising effectiveness.[20,21] Alternatively, the AUC_{24} can be calculated using basic pharmacokinetic equations. The advantages and disadvantages of different methods for monitoring the AUC_{24} are in Table 1.

Table 1 Advantages and disadvantages of different methods for monitoring the area under the concentration–time curve over a 24-hour period (AUC_{24})

Monitoring approach	Description	Advantages	Disadvantages	Examples [NB1]
Pharmacokinetic equations	Uses basic pharmacokinetic equations to calculate vancomycin clearance and volume of distribution, and subsequently, the AUC	Minimal data entry Easy and quick	Requires 2 vancomycin concentrations over a dosing interval for best accuracy. If only one concentration available, population estimates can be used; however, these are less accurate Generally, can only be used at steady state	ClinCalc Sanford
Bayesian dose optimisation software (also known as model-informed precision dosing)	Uses a vancomycin population pharmacokinetic model to provide baseline pharmacokinetic values, then refines these estimates based on the patient's observed drug concentration(s)	Requires one vancomycin concentration Plasma sample can be taken at any time after drug administration Can be used after the first dose; does not need to be at steady state Calculates a patient-specific dosing regimen	Time consuming Requires training in appropriate model selection and interpretation of recommendations	TDMx PrecisePK ID-ODS DoseMe KidsCalc

AUC = area under the concentration–time curve

NB1: At the time of writing, freely available pharmacokinetic calculators or software programs include ClinCalc, TDMx and KidsCalc. Pharmacokinetic calculators or software programs that require a subscription include Sanford, PrecisePK, ID-ODS and DoseMe.

For patients on a continuous infusion of vancomycin, provided the infusion has not been paused within the preceding 24 hours, the vancomycin concentration can by multiplied by 24 to determine an approximate AUC_{24}.

Implementation of vancomycin AUC_{24} monitoring

To transition to AUC_{24}-based monitoring, engagement is required from a variety of stakeholders, including all vancomycin prescribers (not just infectious diseases physicians and clinical microbiologists), pharmacists, nurses and pathology staff.

Depending on resources, sites may prefer to start with a smaller group of patients for AUC_{24}-based monitoring to ensure a safe and manageable process is in place. Patients suggested for prioritisation of vancomycin AUC_{24}-based monitoring are provided in Box 1. Vancomycin trough concentrations cannot provide accurate estimations of the AUC_{24} and it is not guaranteed that a trough concentration of 10 to 15 mg/L is achieving an AUC_{24} of more than 400 mg.hr/L. Therefore, in patients where the risk of not achieving target AUC_{24} is unacceptable (e.g. critically ill; severe, necrotising or deep-seated infections; suspected or confirmed *S. aureus* bacteraemia), AUC_{24}-based monitoring is preferred.

Although AUC_{24} monitoring has become easier with dosing software, education and training of appropriate clinical staff in calculating and interpreting AUC_{24} results are required to ensure safe and appropriate recommendations are made. Different pharmacokinetic models can produce different AUC_{24} results, so appropriate model selection and interpretation are essential.[24] Incorporating some clinical sense checks (e.g. maximum doses) is important so that dosing software recommendations are not blindly followed.

Local protocols for AUC_{24} monitoring should be developed. See Box 2 for examples of information to be included in a protocol.

Changes to target ranges should be updated and displayed on electronic systems where vancomycin concentrations are reported. Ongoing education, review and auditing are needed after implementation of AUC_{24} monitoring.

Reducing the incidence of vancomycin-induced nephrotoxicity

Reducing the incidence of vancomycin-induced nephrotoxicity involves reviewing the patient for risk factors (Box 3), modifying these where possible, and ensuring adequate patient hydration and organ perfusion.

In adults, continuous infusion of vancomycin is associated with a lower risk of AKI.[7,26] In children, a reduction in the rate of nephrotoxicity was not seen when continuous infusion was compared with

ARTICLE

intermittent dosing of vancomycin in a randomised controlled trial.[27]

Multiple observational studies showed an increased risk of AKI with concomitant use of vancomycin and piperacillin+tazobactam compared with vancomycin and other antipseudomonal beta-lactam antimicrobials; however, this risk was not seen in a recent randomised controlled trial and may represent pseudonephrotoxicity (an increase in serum creatinine concentrations without true kidney damage).[28,29] Data supporting nephrotoxicity from concurrent use of vancomycin and flucloxacillin are more compelling; a randomised controlled trial showed nephrotoxicity where the combination was used for 7 days.[8,30]

Important considerations in young infants and children

Young infants (aged zero to 90 days) and children (aged 3 months and older) exhibit different pharmacokinetics and pharmacodynamics from adults. Specialised guidance is provided for:

- loading doses – there is limited evidence to support vancomycin loading doses in children. A small randomised controlled trial found no difference in AUC_{24} target attainment and a trend toward an increased risk of infusion-related reactions in children.[31] A larger multicentre randomised controlled trial found no difference in clinical outcomes in young infants; however, there was a risk of harm (i.e. ototoxicity) when vancomycin loading doses were given[32]
- individualised vancomycin dosing for young infants – given the wide interindividual variability in vancomycin pharmacokinetics in young infants due to rapid changes in organ function, individualised dosing may be preferred. A vancomycin intermittent dosing calculator (KidsCalc) for infants aged zero to 90 days is recommended for individualised dosing in young infants. The calculator is based on an Australian infant 2-compartment pharmacokinetic model,[2,27] and has been prospectively validated in Australia.[33] Use of the doses recommended by the calculator achieves target trough concentrations and AUC_{24} more rapidly, and has not been associated with nephrotoxicity or infusion-related reactions[33]
- vancomycin dose interval – although 12-hourly vancomycin dosing is used in adults, many paediatric centres recommend 6-hourly dosing in children as it has the most supporting pharmacokinetic data to indicate target AUC_{24} attainment

Box 1 Adults in whom monitoring the area under the concentration–time curve over a 24-hour period (AUC_{24}) for vancomycin should be prioritised[22]

Monitoring the area under the concentration–time curve over a 24-hour period (AUC_{24}) for vancomycin should be prioritised in adults who:

- are critically ill or unstable
- have severe, necrotising or deep-seated infections
- have suspected or confirmed *Staphylococcus aureus* bacteraemia
- have obesity
- have augmented renal clearance [NB1]
- are at high risk of acute kidney injury (e.g. patients on concomitant nephrotoxins or who have chronic kidney disease).

NB1: Augmented renal clearance is a term used to describe the enhanced renal function seen in critically ill patients. The use of unadjusted doses of renally eliminated antimicrobials in these patients may result in treatment failure.[23]

Reproduced with permission from: Approach to vancomycin dosing and monitoring in adults [published 2025 Mar]. In: *Therapeutic Guidelines*. Melbourne: Therapeutic Guidelines Limited; accessed 2025 Mar 13 https://www.tg.org.au

Box 2 Information to be included in local hospital protocols about vancomycin area under the concentration–time curve over a 24-hour period (AUC_{24}) monitoring

- Patient inclusion (e.g. specific patient groups or indications that are not suitable for AUC_{24} monitoring)
- Vancomycin monitoring method for patients who are excluded from AUC_{24} monitoring
- Method for vancomycin AUC_{24} calculation
- Timing of collection of plasma samples – if the hospital is implementing a hybrid approach (i.e. AUC_{24} monitoring for only a selected patient group), it may be simpler to continue trough concentration sampling, or the AUC_{24} calculation method may mandate specific collection times or number of concentrations (although for many dosing software programs, samples can be taken at any time from about one hour after administration)
- Method for dosage adjustment when the vancomycin plasma concentration is outside of the target range
- Selection of an appropriate minimum inhibitory concentration
- Training (including who will be trained and who will perform the training)
- Responsibility for AUC_{24} calculation and interpretation of results (including after hours)
- Requirements for monitoring of kidney function – if kidney function significantly changes, previous predictions from dosing software will no longer be accurate

Box 3 Risk factors for vancomycin-induced nephrotoxicity[7,25]

- High vancomycin dosage
- Intermittent infusion of vancomycin (in adults)
- Trough concentrations above 15 mg/L
- Area under the concentration–time curve over a 24-hour period (AUC_{24}) above 600 mg.hr/L
- Obesity
- Critically ill status
- Severe infection
- Pre-existing kidney disease
- Concurrent administration of nephrotoxins or drugs that can affect kidney function (e.g. aminoglycosides, nonsteroidal anti-inflammatory drugs, amphotericin B, loop diuretics, flucloxacillin)

- vancomycin monitoring – AUC_{24} monitoring is recommended in children.[15,34,35] Studies have shown better target attainment and fewer dose adjustments with AUC_{24} monitoring compared with trough concentration monitoring in young infants and children.[36] A reduction in AKI was also found when a paediatric hospital changed from trough concentration monitoring to AUC_{24} monitoring.[37] Similarly to adults, trough concentrations of 15 mg/L or greater are associated with an increased risk of AKI in children.[38]

Conclusion

To optimise vancomycin efficacy and minimise toxicity, AUC_{24}-based monitoring is recommended and should be prioritised in many patient groups. A target AUC_{24} of 400 to 600 mg.hr/L is recommended for most infections (except CNS infections). If AUC_{24} monitoring is unavailable, trough concentration monitoring can be used; however, a lower trough concentration target of 10 to 15 mg/L is now recommended for most clinically stable patients. The patient's clinical context when deciding on a monitoring method should be considered. Hospitals need to consider a safe and sustainable transition plan to AUC_{24} monitoring, including education and training of health professionals. Following implementation, ongoing review and auditing are needed to identify gaps and ensure patient safety and drug effectiveness. <

This article was finalised on 14 March 2025.

Conflicts of interest: all authors were members of the expert group for Therapeutic Guidelines: Antibiotic *version 17.*

Amy Legg received a travel grant from AstraZeneca in 2022. Amy authored the Herston Infectious Diseases Institute's Antimicrobial Therapeutic Drug Monitoring guideline. Amy is a member of the Editorial Advisory Committee for Australian Prescriber. *She was excluded from editorial decision-making related to the acceptance and publication of this article.*

Felicia Devchand is an employee of Therapeutic Guidelines Limited, the publisher of Australian Prescriber.

Amanda Gwee received grant funding from the National Health and Medical Research Council and the Medical Research Future Fund for her research on antimicrobial drugs in paediatric patients.

Indy Sandaradura and Tony Lai received a research grant from Pfizer for the validation of therapeutic drug monitoring assays for isavuconazole, linezolid, ceftaroline and ceftazidime+avibactam in children. Tony has authored antibiotic guidelines for The Children's Hospital at Westmead and the Australian Neonatal Medicines Formulary.

REFERENCES

1. Rybak MJ, Le J, Lodise TP, Levine DP, Bradley JS, Liu C, et al. Therapeutic monitoring of vancomycin for serious methicillin-resistant Staphylococcus aureus infections: 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. Am J Health Syst Pharm 2020;77:835-64. https://doi.org/10.1093/ajhp/zxaa036
2. Gwee A, Duffull SB, Daley AJ, Lim M, Germano S, Bilal H, et al. Identifying a therapeutic target for vancomycin against staphylococci in young infants. J Antimicrob Chemother 2022;77:704-10. https://doi.org/10.1093/jac/dkab469
3. Jumah MTB, Vasoo S, Menon SR, De PP, Neely M, Teng CB. Pharmacokinetic/Pharmacodynamic Determinants of Vancomycin Efficacy in Enterococcal Bacteremia. Antimicrob Agents Chemother 2018;62. https://doi.org/10.1128/AAC.01602-17
4. Bellos I, Pergialiotis V, Perrea DN. Kidney biopsy findings in vancomycin-induced acute kidney injury: a pooled analysis. Int Urol Nephrol 2022;54:137-48. https://doi.org/10.1007/s11255-021-02831-9
5. Kan WC, Chen YC, Wu VC, Shiao CC. Vancomycin-Associated Acute Kidney Injury: A Narrative Review from Pathophysiology to Clinical Application. Int J Mol Sci 2022;23. https://doi.org/10.3390/ijms23042052
6. Chavada R, Ghosh N, Sandaradura I, Maley M, Van Hal SJ. Establishment of an AUC(0-24) Threshold for Nephrotoxicity Is a Step towards Individualized Vancomycin Dosing for Methicillin-Resistant Staphylococcus aureus Bacteremia. Antimicrob Agents Chemother 2017;61. https://doi.org/10.1128/AAC.02535-16
7. Filippone EJ, Kraft WK, Farber JL. The Nephrotoxicity of Vancomycin. Clin Pharmacol Ther 2017;102:459-69. https://doi.org/10.1002/cpt.726
8. Liu J, Tong SYC, Davis JS, Rhodes NJ, Scheetz MH, Group CS. Vancomycin Exposure and Acute Kidney Injury Outcome: A Snapshot From the CAMERA2 Study. Open Forum Infect Dis 2020;7:ofaa538. https://doi.org/10.1093/ofid/ofaa538
9. Pais GM, Liu J, Zepcan S, Avedissian SN, Rhodes NJ, Downes KJ, et al. Vancomycin-Induced Kidney Injury: Animal Models of Toxicodynamics, Mechanisms of Injury, Human Translation, and Potential Strategies for Prevention. Pharmacotherapy 2020;40:438-54. https://doi.org/10.1002/phar.2388
10. Kayode OS, Rutkowski K. Vancomycin Hypersensitivity: It Is Not Always What It Seems. J Allergy Clin Immunol Pract 2021;9:913-5. https://doi.org/10.1016/j.jaip.2020.10.040
11. Alvarez R, Lopez Cortes LE, Molina J, Cisneros JM, Pachon J. Optimizing the Clinical Use of Vancomycin. Antimicrob Agents Chemother 2016;60:2601-9. https://doi.org/10.1128/AAC.03147-14
12. Grayson ML, Cosgrove S, Crowe S, Hope W, McCarthy J, Mills J, et al. Kucers' The Use of Antibiotics: A Clinical Review of Antibacterial, Antifungal, Antiparasitic, and Antiviral Drugs, Seventh Edition - Three Volume Set. CRC Press; 2017.
13. Brusamarello C, Daley AJ, Zhu X, Landersdorfer C, Gwee A. How important are MIC determination methods when targeting vancomycin levels in patients with Staphylococcus aureus infections? J Antimicrob Chemother 2021;76:1641-3. https://doi.org/10.1093/jac/dkab065

ARTICLE

14. European Committee on Antimicrobial Susceptibility Testing. Breakpoint tables for interpretation of MICs and zone diameters. Version 14.0. 2024. http://www.eucast.org. [cited 2025 Mar 5]
15. Lodise TP, Drusano G. Vancomycin Area Under the Curve-Guided Dosing and Monitoring for Adult and Pediatric Patients With Suspected or Documented Serious Methicillin-Resistant Staphylococcus aureus Infections: Putting the Safety of Our Patients First. Clin Infect Dis 2021;72:1497-501. https://doi.org/10.1093/cid/ciaa1744
16. Chen M, Lee C, Gnyra M, Wong M. Vancomycin area under the curve/minimum inhibitory concentration and trough level concordance-evaluation on an urban health unit. Ther Adv Infect Dis 2022;9:20499361221140368. https://doi.org/10.1177/20499361221140368
17. Haag H, Lau A. Correlation of Calculated Vancomycin Trough Concentrations and Exposure: A Monte Carlo Simulation. Ann Pharmacother 2023;57:1410-4. https://doi.org/10.1177/10600280231160571
18. Lewis SJ, Nolin TD. New Vancomycin Dosing Guidelines for Hemodialysis Patients: Rationale, Caveats, and Limitations. Kidney360 2021;2:1313-5. https://doi.org/10.34067/KID.0000192021
19. Heil EL, Claeys KC, Mynatt RP, Hopkins TL, Brade K, Watt I, et al. Making the change to area under the curve-based vancomycin dosing. Am J Health Syst Pharm 2018;75:1986-95. https://doi.org/10.2146/ajhp180034
20. Abdelmessih E, Patel N, Vekaria J, Crovetto B, SanFilippo S, Adams C, et al. Vancomycin area under the curve versus trough only guided dosing and the risk of acute kidney injury: Systematic review and meta-analysis. Pharmacotherapy 2022;42:741-53. https://doi.org/10.1002/phar.2722
21. Lim AS, Foo SHW, Benjamin Seng JJ, Magdeline Ng TT, Chng HT, Han Z. Area-Under-Curve-Guided Versus Trough-Guided Monitoring of Vancomycin and Its Impact on Nephrotoxicity: A Systematic Review and Meta-Analysis. Ther Drug Monit 2023;45:519-32. https://doi.org/10.1097/FTD.0000000000001075
22. Vancomycin monitoring and dosage adjustment in adults. In: Therapeutic Guidelines. Melbourne: Therapeutic Guidelines Limited; 2025. https://www.tg.org.au [cited 2025 Mar 13]
23. Mahmoud SH, Shen C. Augmented Renal Clearance in Critical Illness: An Important Consideration in Drug Dosing. Pharmaceutics 2017;9. https://doi.org/10.3390/pharmaceutics9030036
24. Patanwala AE, Spremo D, Jeon M, Thoma Y, JW CA, Stocker S. Discrepancies Between Bayesian Vancomycin Models Can Affect Clinical Decisions in the Critically Ill. Crit Care Res Pract 2022;2022:7011376. https://doi.org/10.1155/2022/7011376
25. Legg A, Meagher N, Johnson SA, Roberts MA, Cass A, Scheetz MH, et al. Risk Factors for Nephrotoxicity in Methicillin-Resistant Staphylococcus aureus Bacteraemia: A Post Hoc Analysis of the CAMERA2 Trial. Clin Drug Investig 2023;43:23-33. https://doi.org/10.1007/s40261-022-01204-z
26. Flannery AH, Bissell BD, Bastin MT, Morris PE, Neyra JA. Continuous Versus Intermittent Infusion of Vancomycin and the Risk of Acute Kidney Injury in Critically Ill Adults: A Systematic Review and Meta-Analysis. Crit Care Med 2020;48:912-8. https://doi.org/10.1097/CCM.0000000000004326
27. Gwee A, Cranswick N, McMullan B, Perkins E, Bolisetty S, Gardiner K, et al. Continuous Versus Intermittent Vancomycin Infusions in Infants: A Randomized Controlled Trial. Pediatrics 2019;143. https://doi.org/10.1542/peds.2018-2179
28. Qian ET, Casey JD, Wright A, Wang L, Shotwell MS, Siemann JK, et al. Cefepime vs Piperacillin-Tazobactam in Adults Hospitalized With Acute Infection: The ACORN Randomized Clinical Trial. JAMA 2023;330:1557-67. https://doi.org/10.1001/jama.2023.20583
29. Bellos I, Karageorgiou V, Pergialiotis V, Perrea DN. Acute kidney injury following the concurrent administration of antipseudomonal beta-lactams and vancomycin: a network meta-analysis. Clin Microbiol Infect 2020;26:696-705. https://doi.org/10.1016/j.cmi.2020.03.019
30. Tong SYC, Lye DC, Yahav D, Sud A, Robinson JO, Nelson J, et al. Effect of Vancomycin or Daptomycin With vs Without an Antistaphylococcal beta-Lactam on Mortality, Bacteremia, Relapse, or Treatment Failure in Patients With MRSA Bacteremia: A Randomized Clinical Trial. JAMA 2020;323:527-37. https://doi.org/10.1001/jama.2020.0103
31. Demirjian A, Finkelstein Y, Nava-Ocampo A, Arnold A, Jones S, Monuteaux M, et al. A randomized controlled trial of a vancomycin loading dose in children. Pediatr Infect Dis J 2013;32:1217-23. https://doi.org/10.1097/INF.0b013e3182a26774
32. Hill LF, Clements MN, Turner MA, Dona D, Lutsar I, Jacqz-Aigrain E, et al. Optimised versus standard dosing of vancomycin in infants with Gram-positive sepsis (NeoVanc): a multicentre, randomised, open-label, phase 2b, non-inferiority trial. Lancet Child Adolesc Health 2022;6:49-59. https://doi.org/10.1016/S2352-4642(21)00305-9
33. Wilkins AL, Lai T, Zhu X, Bolisetty S, Chiletti R, Cranswick N, et al. Individualized vancomycin dosing in infants: prospective evaluation of an online dose calculator. Int J Antimicrob Agents 2023;61:106728. https://doi.org/10.1016/j.ijantimicag.2023.106728
34. Abdulla A, Edwina EE, Flint RB, Allegaert K, Wildschut ED, Koch BCP, et al. Model-Informed Precision Dosing of Antibiotics in Pediatric Patients: A Narrative Review. Front Pediatr 2021;9:624639. https://doi.org/10.3389/fped.2021.624639
35. Han J, Sauberan J, Tran MT, Adler-Shohet FC, Michalik DE, Tien TH, et al. Implementation of Vancomycin Therapeutic Monitoring Guidelines: Focus on Bayesian Estimation Tools in Neonatal and Pediatric Patients. Ther Drug Monit 2022;44:241-52. https://doi.org/10.1097/FTD.0000000000000910
36. Hughes DM, Goswami S, Keizer RJ, Hughes MA, Faldasz JD. Bayesian clinical decision support-guided versus clinician-guided vancomycin dosing in attainment of targeted pharmacokinetic parameters in a paediatric population. J Antimicrob Chemother 2020;75:434-7. https://doi.org/10.1093/jac/dkz444
37. Olson J, Hersh AL, Sorensen J, Zobell J, Anderson C, Thorell EA. Intravenous Vancomycin Therapeutic Drug Monitoring in Children: Evaluation of a Pharmacy-Driven Protocol and Collaborative Practice Agreement. J Pediatric Infect Dis Soc 2020;9:334-41. https://doi.org/10.1093/jpids/piz036
38. Fiorito TM, Luther MK, Dennehy PH, LaPlante KL, Matson KL. Nephrotoxicity With Vancomycin in the Pediatric Population: A Systematic Review and Meta-Analysis. Pediatr Infect Dis J 2018;37:654-61. https://doi.org/10.1097/INF.0000000000001882