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Preserved renal function is associated with early subtherapeutic vancomycin exposure after conventional 15 mg/kg loading doses in non-critically ill patients receiving continuous infusion: a prospective multicenter cohort study (VANCOCINEMA)

GALY Adrien
adrien.galy@aphp.fr

Assistance Publique – Hôpitaux de Paris
Marine Lemaitre
Centre Hospitalier du Mans
Guillaume Bianconi
Centre Hospitalier de Versailles
Clément Ourghanlian
Assistance Publique – Hôpitaux de Paris
Samuel Bensaid
Assistance Publique – Hôpitaux de Paris
Simon Rolland
Assistance Publique – Hôpitaux de Paris
David Lebeaux
Assistance Publique – Hôpitaux de Paris
Alexandre Bleibtreu
Assistance Publique – Hôpitaux de Paris
Dorothée Vignes
Hôpital Antoine-Béclère
Etienne Canouï
Assistance Publique – Hôpitaux de Paris
Annelise Lecapitaine
Centre Hospitalier Compiègne-Noyon
Axelle De Raignac Licha
Institut Hospitalier Franco Britannique
Anne Lise Munier
Assistance Publique – Hôpitaux de Paris
Amélie Chabrol
Centre Hospitalier Sud Francilien
Carine Couzigou
Hôpital Paris Saint-Joseph
Clemence Richaud
Institute Mutualiste Montsouris
Eloy Philippine
Assistance Publique – Hôpitaux de Paris
LEFORT Agnès
Université Paris Cité

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Abstract

Background A 30 mg/kg vancomycin (Va) loading dose (LD) is recommended to achieve early therapeutic concentrations in critically ill patients, but the optimal LD in non-critically ill patients remains unknown. We investigated the association between Va LD and achievement of optimal plasma concentration (20–30 mg/L) 36±12h after LD in non-ICU patients.

Materials Consecutive hospitalized adults receiving a Va LD followed by continuous infusion between June and October 2021 in 12 tertiary care hospitals were prospectively included. Va plasma concentrations were measured 36±12h after LD. Logistic regression analyses were performed to identify factors associated with non-optimal concentrations.

Results Overall, 105 patients were included: 76 (72%) received 15±5 mg/kg (group 1), 9 (9%) 20–25 mg/kg (group 2), and 20 (19%) 30±5 mg/kg (group 3). Median age was 62 years and 57% were male; 51% were immunocompromised. Median Va plasma concentration was 19 mg/l overall, and 17, 20 and 22 in groups 1, 2 and 3, respectively. Optimal concentrations were achieved in 36/105 patients (34%), and in 21/76 (28%), 4/9 (44%) and 11/20 (55%) in groups 1, 2 and 3, respectively; 45/76 (59%) group 1 versus 8/20 (40%) group 3 patients were underdosed.

In multivariate analysis, baseline glomerular filtration rate < 90 mL/min/1.73m² (aOR 0.14; p<0.001) and a 30±5 mg/kg LD (aOR 0.23; p=0.015) were independently associated with lower risk of underdosing.

Conclusion Conventional 15 mg/kg loading doses frequently resulted in subtherapeutic vancomycin exposure, particularly in patients with preserved renal function. Larger prospective studies are warranted to determine whether higher loading doses improve early target attainment in non-critically ill patients.

KEY MESSAGE

- Conventional 15 mg/kg loading doses frequently resulted in subtherapeutic vancomycin exposure.
- Preserved renal function was independently associated with underexposure.
- Strategies to improve early target attainment in non-ICU patients deserve prospective evaluation.

INTRODUCTION

Vancomycin, a glycopeptide antibiotic, remains the gold standard treatment for severe infections caused by methicillin-resistant Gram-positive cocci, particularly methicillin-resistant *Staphylococcus aureus* (MRSA) (1, 2). Its therapeutic success is closely tied to achieving and maintaining adequate plasma concentrations, measured by the area under the curve (AUC)/minimum inhibitory concentration (MIC) ratio. A ratio exceeding 400 is predictive of clinical and microbiological success (3, 4). Optimal administration requires a tailored regimen, including a loading dose (LD) followed by continuous infusion (1, 2). This approach facilitates rapid achievement of therapeutic levels and reduces toxicity risks compared to intermittent dosing (1, 2, 5–7). While elevated LD (25–30 mg/kg) are recommended for critically ill patients to account for altered pharmacokinetics (8–14), there is little evidence supporting their routine use in non-critical settings (15) as patients in general wards exhibit different pharmacokinetic profiles. Applying higher LD in such patients as proposed for some patients by IDSA guidelines (2), or SPILF / GPR (16) may increase the risk of vancomycin-associated nephrotoxicity and infusion-related reactions, such as "Red-man syndrome" (17–19). A recent observational study of intravenous vancomycin prescription practices of French infectious disease specialists showed a great heterogeneity in loading dose among continuous administration users, which was 15 mg/kg or less in 49%, 20–25 mg/kg in 20% and 30 mg/kg or more in 28% (20).

The primary objective of this study was to prospectively evaluate the correlation between the vancomycin LD and the vancomycin plasma concentration at 36h (± 12h) in non-ICU hospitalized patients treated with continuous vancomycin infusion, in order to determine the most appropriate LD for this population.

METHODS

Patient selection and study design

This prospective multicentric observational study was conducted in twelve tertiary-care hospitals from Ile-de-France region, France. All consecutive non-ICU hospitalized adult patients receiving a LD (based on actual body weight) followed by a continuous maintenance dose of vancomycin were eligible. They were prospectively included if a plasma vancomycin concentration monitoring was performed 36h (± 12h) after the LD (1, 2, 21). Patients were enrolled during two one-month periods: June–July 2021 and October–November 2021. Given the previously described heterogeneity of practices among French infectious disease specialists regarding vancomycin loading dose, we hypothesized that loading doses would differ between centers (20).

Patients were not included if they were hospitalized in ICU at the time of the LD, or were unable to consent. The study was in accord with the ethical standards on human experimentation and approved by the hospital's institutional review board (N° CER-2021-65). All participating patients gave written informed consent.

Definitions and follow-up

The infectious disease specialists of the participating centers included patients. Data collection occurred at the reception of the result of the plasma vancomycin concentration, i.e., between the 2nd and 4th day of treatment. As this was an observational study, clinical management and treatment of patients were the responsibility of the patient's referent physician.

Plasma concentrations of vancomycin was assayed by enzyme-linked immunoturbidimetry on a Cobas 8000 Roche Diagnostics, Switzerland). The lower and upper limits of quantification were 4 and 80 mg/L, respectively. The method was validated and certified by Health and Quality authorities Cofrac (French accreditation committee). External quality controls were regularly assessed, in accordance with international recommendations.

Immunocompromised patients were defined as: HIV infected with CD4 counts below 200/mm³, progressive solid tumors, progressive malignant hematologic diseases, immunosuppressive treatments, neutropenia, solid organ transplants, diabetes.

Study Outcome:

The primary outcome was the percentage of patients achieving plasma vancomycin levels between 20 and 30 mg/L at 36 hours (± 12 hours) after treatment initiation, considered as the optimal vancomycin plasma concentration (1, 2). In patients receiving continuous infusion, plasma vancomycin concentrations approach steady-state rapidly after the loading dose. A measurement performed at 36 hours (± 12 hours) was therefore chosen as a pragmatic time point to assess early target attainment, reflecting routine clinical practice across participating centers. Secondary outcomes included treatment safety (renal toxicity and cutaneous reactions), practice variations according to patient and prescriber characteristics, and the proportion of patients with underexposure (< 20 mg/L) or overexposure (> 30 mg/L).

Statistical analysis

First, a descriptive analysis was performed. Categorical variables were summarized as counts (percentage), and frequency distributions were compared with the Chi square test or the Fisher exact test as appropriate. Continuous variables were expressed as median (IQR), and differences were tested with the independent t-test for normally distributed variables (assessed by the Shapiro-Wilk test) or the Mann-Whitney U test if otherwise.

Second, we searched for factors associated with under- or over-exposition to vancomycin 24–48 hours after the LD among the following variables at baseline: demographic characteristics (age, weight, body mass index), comorbidities (altered glomerular filtration rate, immunodeficiency), laboratories results (baseline glomerular filtration rate (eGFR), glomerular filtration rate measured on the day of the plasma vancomycin concentration monitoring, albumin, total protein, leukocyte count) and infection characteristics (empiric antibiotic therapy, bacterial species, infection site, qSOFA score). Variables with a p-value < 0.20 in the bivariate analysis were tested in multivariate models. The variable selection was performed using a stepwise multivariable logistic regression with p-value cut-off point of 0.05. Two-way interactions between risk factors kept in the multivariate analysis were tested. All statistical analyses were conducted using R version 4.2.1.

RESULTS

Patients' characteristics

Overall, 105 patients were included, and categorized in three LD groups: 15 ± 5 mg/kg for 76 (72%, group 1),]20 - 25[for 9 (9%, group 2) and 30 ± 5 mg/kg for 20 (19%, group 3). Patient's characteristics at baseline are presented in Table 1. Median age was 62 years [51–72], 57% were male (n=60), and 51% were immunocompromised (n=53). Half of the patients were hospitalized in surgical units, and treated for skin/catheter or osteoarticular infections (56%, n = 59). Vancomycin was used as an empiric antibiotic therapy in 44% (n=46). Five patients presented a qSOFA score at baseline of two or more (5%), without necessity of a transfer in an intensive care unit. No major difference in the patients' baseline characteristics between the three LD groups was observed.

Practices for vancomycin administration varied across centers. Peripheral venous lines were used for loading dose administration in 69% (n = 68/99 responders), with 58% (n = 68/99) using dedicated lines. Infusion times were predominantly 60–120 minutes (89%, n = 92/103).

Primary outcome

Median vancomycin plasma concentration was 19 [15-25] mg/l in the overall population, and 17 [14-24], 20 [18-25] and 22 [16-26] in groups 1, 2 and 3 respectively, as shown in Table 2. The proportion of patient who achieved an optimal vancomycin plasma concentration, 36h ± 12h after the LD, in the overall population was 36/105 patients (34%). A non-statistically significant (p=0.15) proportion of patients from the group 3 reached the optimal vancomycin plasma concentration (55%, n=11/20), as compared to the proportions in the group 1 (28%, n=21/76) and the group 2 (44%, n=4/9). Conversely, 59% (n = 45/76) of patients in group 1 were under-dosed, compared to 40% of patients in group 3 (n = 8/20) and 33% in group 2 (n = 3/9).

Maintenance dose was similar in the three groups, being 30 ±5 mg/kg in 83% (n = 87/105). The delay between vancomycin dosage and loading dose administration varied between the three groups as shown in Table 2, without being significantly associated with vancomycin plasma concentration categories (χ^2 test, p = 0.25; Table S1, supplemental data, Table S1).

Associated factor resulting in under or over exposition

Multivariate analysis identified two factors as protective against the risk of under-dosing: a baseline glomerular filtration rate (GFR) under 90 ml/min/1.73m2 (aOR 0.14 [0.05–0.39]; p < 0.01) and a 30 ±5 mg/kg LD (aOR 0.23 [0.07–0.76]; p = 0.02), as shown in Table 3. For overexposure, no single factor demonstrated strong predictive significance. Vancomycin plasma concentrations according to loading dose and baseline glomerular filtration rate are shown in Figure 1.

Safety, Tolerance and Administration issues

No case of "Red-man syndrome" or immediate severe skin toxicity were observed. Renal function changes in glomerular filtration rate were minimal and non-significant across groups, varying from +11.4, +4.1 and +3.2 mL/min/1.73m2 in patient in the group 1, 2 and 3 respectively, as shown in Table 2.

Table 1 - Patients' baseline characteristics

	Overall population n = 105	Group 1 Loading dose 15 ± 5 mg/kg n = 76	Group 2 Loading dose]20-25[mg/kg n = 9	Group 3 Loading dose 30 ± 5 mg/kg n = 20	p
Recruiting centers					0.36
Hospital n°1, n (%)	49 (47)	35 (46)	4 (44)	10 (50)	
Hospital n°2, n (%)	21 (20)	17 (22)	2 (22)	2 (10)	
Hospital n°3, n (%)	20 (19)	16 (21)	2 (22)	2 (10)	
Other hospitals (8 centers), n (%)	15 (14)	8 (11)	1 (11)	6 (30)	
Demographic characteristics					
Age, yr., median [IQR]	62 [51 - 72]	62 [51 - 11]	66 [61 - 81]	62 [50 - 68]	0.40
Male, n (%)	60 (57)	44 (58)	3 (33)	13 (65)	0.27
Weight, kg, median [IQR]	71 [59 - 82]	68 [57 - 80]	85 [70 - 93]	73 [67 - 80]	0.07
Size, cm, median [IQR]	170 [159 - 177]	169 [160 - 176]	170 [156 - 175]	170 [164 - 177]	0.70
Body mass index, median [IQR]	25 [21 - 28]	25 [21 - 28]	28 [25 - 30]	25 [21 - 28]	0.03
Hospitalization wards					0.85
Surgery units, n (%)	51 (49)	35 (46)	5 (56)	11 (55)	
Infectious Disease units, n (%)	2 (2)	1 (1)	0 (0)	1 (5)	
Internal medicine units, n (%)	5 (5)	4 (5)	0 (0)	1 (5)	
Other medical units, n (%)	47 (45)	36 (47)	4 (44)	7 (35)	
Comorbidities					
Immunodeficiency, n (%)	53 (51)	42 (55)	5 (56)	6 (20)	0.13
Neoplasia, n (%)	26 (25)	21 (28)	2 (22)	3 (15)	
Hemopathy, n (%)	20 (19)	16 (21)	2 (22)	2 (10)	
Immunosuppressive treatment or solid organ transplantation, n (%)	7 (7)	5 (7)	1 (11)	1 (5)	
Glomerular filtration rate < 30 mL/min /1,73 m^2, n (%)	3 (3)	2 (3)	1 (11)	0 (0)	0.25
Laboratory results					
Albuminemia, g/L, median [IQR]	27 [23 - 30]	27 [24 - 30]	32 [29 - 36]	26 [20 - 28]	0.11
Proteinemia, g/L, median [IQR]	61 [56 - 67]	61 [56 - 66]	63 [59 - 70]	59 [52 - 68]	0.50
Creatininemia, µmol/L, median [IQR]	67 [55 - 81]	64 [53 - 80]	72 [67 - 90]	70 [55 - 73]	0.30
Polynuclear neutrophils, G/L, median [IQR]	5 [3 - 9]	5 [3 - 10]	3 [2 - 8]	6 [4 - 9]	0.70
Leukocyte < 1 G/L, n (%)	11 (10)	8 (11)	2 (22)	1 (5)	0.38
Infection characteristics					
Probabilistic antibiotic therapy, n (%)	46 (44)	35 (46)	3 (33)	8 (40)	0.71
qSOFA score ≥ 2, n (%)	5 (5)	4 (5)	0 (0)	1 (5)	0.78
Microbiological characteristics					0.66
Coagulase negative staphylococci, n (%)	33 (34)	22 (29)	4 (44)	7 (35)	
Staphylococcus aureus, n (%)	9 (9)	6 (8)	0 (0)	3 (15)	
Streptococcus or *Enterococcus*, n (%)	19 (18)	14 (18)	3 (33)	2 (10)	

Other, n (%)	12 (12)	10 (13)	0 (0)	2 (10)	
None, n (%)	32 (35)	24 (32)	2 (22)	6 (30)	
Infection site					0.43
Digestive/urologic, n (%)	18 (17)	15 (20)	0 (0)	3 (15)	
Skin or catheter, n (%)	25 (24)	17 (22)	5 (56)	3 (15)	
Osteoarticular, n (%)	34 (32)	24 (32)	3 (33)	7 (35)	
Other, n (%)	21 (20)	15 (20)	1 (11)	5 (25)	
Not specified, n (%)	7 (7)	5 (7)	0 (0)	2 (10)	

IQR interquartile range, yr. year

Table 2 – Characteristics of vancomycin plasma concentration at 36h (±12h) and glomerular filtration rate variation, according to loading dose group

	Overall population	Group 1	Group 2	Group 3	p
		Loading dose	Loading dose	Loading dose	
	n = 105	15 ± 5 mg/kg	]20-25[mg/kg	30 ± 5 mg/kg	
		n = 76	n = 9	n = 20	
Vancomycin plasma concentration, mmol//L, median [IQR]	19 [15 - 25]	17 [14 - 24]	20 [18 - 25]	22 [16 - 26]	0.30
Therapeutic zone, mmol//L					0.125
Underdosed (< 20), n (%)	56 (53)	45 (59)	3 (33)	8 (40)	
Optimal ([20 - 30]), n (%)	36 (34)	21 (28)	4 (44)	11 (55)	
Overdosed (> 30), n (%)	13 (12)	10 (13)	2 (22)	1 (5)	
Delay between vancomycin dosage and loading dose administration, hours					0.045
< 30, n (%)	18 (17)	10 (13)	1 (11)	7 (35)	
[30 - 42], n (%)	61 (58)	48 (63)	3 (33)	10 (50)	
> 42, n (%)	26 (25)	18 (24)	5 (56)	3 (15)	
Glomerular filtration rate variation from loading dose administration to vancomycin dosage (mL/min/1.73m2), median [IQR]	9.9 [-2.1 - 32.2]	11.4 [-0.8 - 30.9]	4.1 [-0.3 - 37.1]	3.2 [-5.4 - 40.0]	0.60
NA, n (%)	25 (24)	17 (22)	4 (44)	4 (20)	

IQR interquartile range, NA : not assessed

Table 3 – Bivariate and multivariate logistic regressions of the association of patient's characteristics and vancomycin plasma concentration in under-exp

	Bivariate							**Multivariate**
	Inside the therapeutic range n=36	Under-exposed n=56	**OR (95% CI)**	**p**	Over-exposed n=13	**OR (95% CI)**	**p**	**aOR Under-exposed (95% CI)**
Age (>=75), n (%)	12/36 (33)	6 /56 (11)	0.24 [0.08 - 0.72]	**0.01**	2 /13 (15)	0.36 [0.07 - 1.91]	**0.2**	
Female sex, n (%)	19/36 (53)	19/56 (34)	0.46 [0.20 - 1.08]	**0.08**	7 /13 (54)	1.04 [0.29 - 3.72]	>0.9	
Baseline glomerular filtration rate <90 (mL/min/1.73m2), n (%)	22/36 (61)	12/56 (21)	0.17 [0.07 - 0.44]	**<0.01**	6 /13 (46)	0.55 [0.15 - 1.96]	0.4	0.14 [0.05 - 0.39
Loading dose per kg n (%)								
]20-25[	4 /36 (11)	3 /56 (5)	0.35 [0.07 - 1.71]	**0.2**	2 /13 (15)	1.05 [0.16 - 6.72]	>0.9	0.41 [0.07 - 2.32
30 ± 5	11/36 (31)	8 /56 (14)	0.34 [0.12 - 0.97]	**0.04**	1 /13 (8)	0.19 [0.02 - 1.69]	**0.14**	0.23 [0.07 - 0.76
Delay (h)								
<30	8/36 (22)	9/56 (16)	0.49 [0.16 – 1.49]	**0.2**	2 /13 (15)	0.25 [0.03 – 2.36]	**0.2**	
>42	12/36 (33)	10/56 (18)	0.36 [0.13 – 1.00]	**0.05**	1 /13 (8)	0.67 [0.16 – 2.74]	**0.6**	
Immunodeficiency, n (%)								
Neoplasia	12/36 (33)	14/56 (25)	0.73 [0.28 - 1.96]	0.3	0 /13 (0)	0 [0 - 0]	0.6	
Hemopathy	4 /36 (11)	13/56 (23)	2.05 [0.57 - 7.32]	0.5	3 /13 (23)	1.59 [0.29 - 8.86]	0.8	
Other	3 /36 (8)	2 /56 (4)	0.42 [0.06 - 2.77]	0.4	2 /13 (15)	1.42 [0.20 - 10.2]	0.7	
Proteinemia (g/L), median [IQR]	59 [54 - 66]	63 [57 - 69]	1.03 [0.98 - 1.09]	0.2	59 [54 - 63]	0.97 [0.89 - 1.04]	0.4	

OR = Odds Ratio, CI = Confidence Interval, aOR = ajusted Odds Ratio, OR, associated 95% CI and p-value to Wald test are displayed for each regression meth
were obtained after backward selection

DISCUSSION

In this study, a conventional 15 mg/kg vancomycin loading doses frequently failed to achieve early therapeutic plasma concentrations in non-critically ill hospitalized patients receiving continuous infusion (59%, n = 45/76). Patients with preserved renal function were particularly prone to early subtherapeutic exposure (72%, n = 34/7) (supplemental data, Table S2), whereas both a 30 mg/kg loading dose and a baseline glomerular filtration rate below 90 mL/min/1.73 m² were independently associated with a lower risk of underdosing. These findings suggest that current loading-dose strategies may be insufficient for a substantial proportion of patients outside the intensive care setting.

Current recommendations regarding vancomycin loading doses have largely been extrapolated from critically ill populations, in whom an initial dose of 25–30 mg/kg is recommended to rapidly achieve therapeutic exposure (1, 2, 9–12). However, evidence supporting these recommendations in non-critically ill patients remains scarce (15, 22). Because continuous infusion aims to achieve therapeutic concentrations as early as possible, inadequate initial exposure may delay effective treatment during the first days of therapy and expose patients to treatment inefficacy (3, 4, 19, 21, 23, 24). Our study therefore addresses an important knowledge gap by specifically evaluating early target attainment in hospitalized patients managed outside the ICU.

The most clinically relevant finding of our study is not the apparent benefit of the 30 mg/kg loading dose itself, but rather the high frequency of subtherapeutic exposure observed with conventional loading doses, especially among patients with preserved renal function. Although higher loading doses were associated with improved target attainment (not statistically significant), our observational design and limited patients receiving 30mg/Kg loading doses precludes establishing causality. In contrast, the independent association between preserved renal function and underexposure strongly supports the biological plausibility that rapid vancomycin clearance contributes to insufficient early drug exposure. This observation is consistent with current pharmacokinetic knowledge showing that vancomycin clearance closely follows glomerular filtration and suggests that standard loading doses may be inadequate for patients with preserved renal function even outside the context of augmented renal clearance described in critically ill patients (19, 23, 24) and necessitate careful monitoring and dosage adjustments to achieve therapeutic efficacy while minimizing toxicity (25–28). Therapeutic drug monitoring remains essential, particularly in patients with modified renal function or concomitant nephrotoxic therapies (28–30)

Only one third of patients achieved the predefined therapeutic, highlighting the limitations of current practice. Similar difficulties in achieving early therapeutic concentrations have been reported in previous studies evaluating continuous vancomycin infusion, although most were performed in critically ill patients or included heterogeneous dosing strategies (8–10, 12). Our findings extend these observations to a prospective multicenter cohort of non-critically ill patients and identify renal function as a major determinant of early target attainment.

Our study relied on plasma vancomycin concentrations rather than AUC-based monitoring. Although AUC/MIC is now considered the optimal PK/PD target (21), its routine implementation remains limited in many centers, particularly outside the ICU (21). In the context of continuous infusion, steady-state plasma concentration is commonly used as a practical surrogate of exposure and remains widely applied in daily clinical practice. The present study was therefore designed to evaluate dosing strategies under real-life conditions, rather than to assess model-based precision dosing approaches. Further research is needed to refine dosing protocols for non-ICU patients, including the integration of real-time AUC monitoring into clinical practice (10, 19, 25, 27, 31, 32). Randomized controlled trials comparing different strategies of loading and maintenance dose regimens or optimized vancomycin treatment using population pharmacokinetics models could provide more definitive evidence.

Importantly, our study was not designed to evaluate the safety of higher loading doses. Vancomycin concentrations were assessed only during the first 36 ± 12 hours, and patients were not followed for delayed nephrotoxicity or other adverse events. Consequently, although no immediate safety signal was identified, our data should not be interpreted as demonstrating the safety of higher loading doses. Rather, they indicate that higher initial doses deserve prospective evaluation with both pharmacokinetic and clinical safety endpoints.

Our study has several limitations. First, the observational design introduces the possibility of indication bias, as loading doses were prescribed according to local clinical practice rather than random allocation. Second, only twenty patients received a loading dose of approximately 30 mg/kg, limiting statistical power for comparisons between dose groups. Third, therapeutic concentrations were evaluated using a single early plasma measurement, without assessment of cumulative exposure or clinical outcomes. Finally, no follow-up data regarding nephrotoxicity or treatment efficacy were collected, preventing conclusions regarding the clinical impact of improved early target attainment.

Despite these limitations, our study also has important strengths. It is, to our knowledge, one of the few prospective multicenter studies specifically evaluating vancomycin loading-dose strategies in non-critically ill hospitalized patients receiving continuous infusion. The prospective design, standardized therapeutic drug monitoring and inclusion of twelve tertiary-care hospitals enhance the generalizability of our findings and provide robust real-world pharmacokinetic data.

CONLUSION

Conventional 15 mg/kg loading doses frequently resulted in early subtherapeutic vancomycin exposure in non-critically ill hospitalized patients, particularly in those with preserved renal function. These findings suggest that current loading-dose strategies may not provide adequate early drug exposure in this population and support prospective studies evaluating individualized or higher loading-dose regimens according to renal function.

Declarations

Conflict of interest:

The authors report no conflicts of interest.

Funding:

None.

Author Contribution

Authors' contribution: A.G., M.L., P.E and A.L. contributed to the conception and design of the study, overviewed the conduct of the project and participated in the interpretation of the data and critical revision of the manuscript. A.G., M.L., C.O., S.B., S.R., D.L., A.B., D.V., E.C., AL.L., DR.L., AL.M., A.C., C.C., C.R., C.P. and A.L participated in data collection. G.B. and P.E. realized statistical analysis. A.G., M.L., P.E., G.B. and A.L. contributed to the analysis and the interpretation of the data and in critical revision of the manuscript. A.G., P.E., G.B. analyzed all the data and prepared figures and tables. A.G. authored the manuscript. All authors gave the final approval for this version of the manuscript. The corresponding author had full access to all the data and had final responsibility for the decision to submit for publication.Funding: None.Conflict of interest: The authors report no conflicts of interest.

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Figures

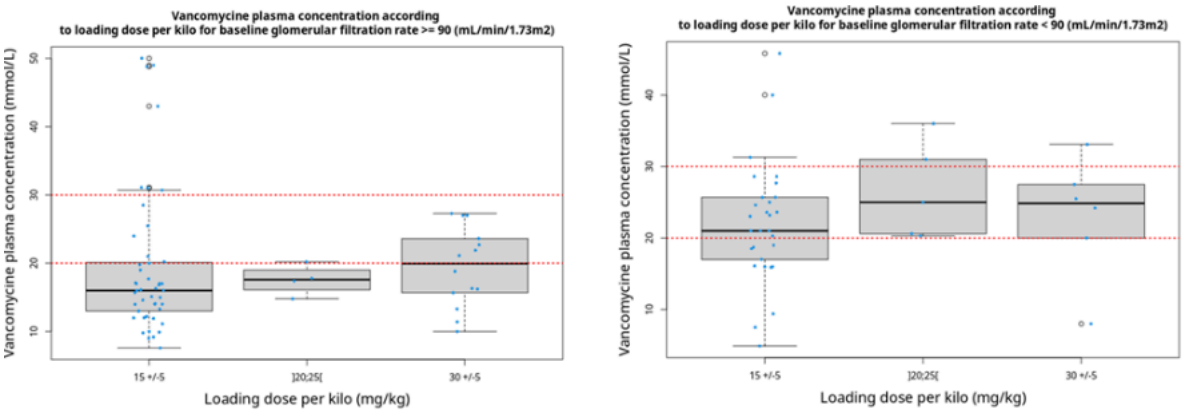


Figure 1

Vancomycin plasma concentration according to loading dose and baseline glomerular filtration rate

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