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Vancomycin versus linezolid for treatment of staphylococcal-associated central nervous system infections

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Abstract

Background Linezolid and vancomycin are both recommended for the treatment of staphylococcal-associated central nervous system (CNS) infections. However, to date, no data are available comparing the outcomes of patients treated with vancomycin or linezolid for these infections. The aim of this study was to compare the incidence of treatment failure and adverse events (AEs) associated with vancomycin and linezolid in staphylococcal-associated CNS infections.

Methods This retrospective monocentric observational study was conducted between 01/01/2015 and 31/12/2023. All patients with a confirmed staphylococcal associated CNS infection and treated with vancomycin or linezolid were included. Failure of antimicrobial treatment was the primary outcome of interest, defined by a composite criteria: persistence of infection (i.e. positive culture after > 72 h of antimicrobial treatment active on the isolated bacteria), relapse of infection (i.e. new infection with the same bacteria involved in the initial episode) or infection related death. Second outcome of interest was AE incidence related to linezolid or vancomycin. Outcomes were analysed using survival analysis techniques and propensity score.

Results Ninety one patients were included: 51 in vancomycin group and 40 in linezolid group. Infections were mainly meningitis ($n=71$; 78%). Median duration of linezolid or vancomycin treatment was 7 days (IQR 4; 13). Treatment failure occurred in 18.6% ($n=17$) of patients (infection persisted in 9.8% of patients ($n=9$), infection relapsed in 6.6% ($n=6$) and infection caused a fatal outcome in 4.4% ($n=4$). In the Cox proportional hazards regression model, vancomycin was not associated with treatment failure (aHR 2.90; 95% CI [0.93–9.30]; $p=0.066$). Using propensity score, vancomycin was associated with treatment failure (HR 3.28; 95% CI [1.02–10.54]; $p=0.045$). Treatment with vancomycin was also associated with AE (HR 8.42; CI 95% [2.44;29.10]; $p=0.019$).

Conclusion Patients treated with vancomycin for staphylococcal-associated CNS infections seems to have a higher risk of treatment failure and AE compared to those treated with linezolid. However, given the low statistical power and the observational nature of this study, further research is needed to confirm these findings.

Keywords Linezolid, Vancomycin, Central nervous system infections, Healthcare-associated infections

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Introduction

Healthcare associated central nervous system (CNS) bacterial infections are rare but challenging to treat infections with high morbidity and mortality [1]. *Staphylococcus aureus* and coagulase-negative staphylococci (CoNS) are the main Gram-positive bacteria involved healthcare-associated CNS infections, and methicillin resistance must be considered when starting an empirical treatment [1–3]. Thus, vancomycin is recommended by the Infectious Diseases Society of America (IDSA) and the European Society of Clinical Microbiology and Infectious Disease (ESCMID) as the first line agent to treat healthcare associated CNS infection [1, 3]. Vancomycin has bactericidal activity against methicillin-resistant staphylococci (MRS) with cerebrospinal fluid (CSF)-to-plasma concentrations ratio of about 30% in case of CNS inflammation [4] and its efficacy in CNS infections is well documented [5]. To achieve adequate CSF or brain concentrations, high doses of vancomycin are recommended [1, 3]. However, these high doses of vancomycin may increase risk of serious adverse events (AE): several reports are correlating high serum concentration of vancomycin with acute kidney injury [6, 7]. Linezolid, an oxazolidinone effective against Gram-positive resistant strains of staphylococci is recommended by international guidelines as alternative agent to treat healthcare associated CNS infection [1, 3]. Linezolid has a CSF-to-plasma concentrations ratio from 70–90% [4, 8] and several data reporting efficacy of linezolid for treating staphylococcal associated CNS infections [9–11]. However to date, there is no data comparing outcomes of patients treated by vancomycin or linezolid for staphylococcal associated CNS infections. Thus, the aim of this study was to compare the incidence of treatment failure and AE associated with vancomycin and linezolid for staphylococcal-associated CNS infections.

Methods

Study population

This retrospective monocentric observational study was conducted between 01/01/2015 and 31/12/2023 at the University Hospital of Bordeaux. All patients with at least one *Staphylococcus aureus* positive culture or two or more positive cultures for CoNS from CNS sources (i.e., CSF, intracranial samples, or neurosurgical implants) were included. Paediatric patients (under 18 years old), patients with fewer than two CoNS positive cultures from CNS sources, and patients who were not treated with linezolid or vancomycin were excluded. Overall, all adult patients with staphylococcal associated CNS infections treated with at least one dose of vancomycin or linezolid during the study period were included.

Data collection

Demographic data, medical history, neurosurgical condition, infection characteristics, clinical, antimicrobial treatment characteristics, adverse events related to vancomycin or linezolid and outcomes were collected from electronic health records.

Definition

Meningitis was defined as CSF pleocytosis ($>5/mm^3$) and an increasing CSF white cell count from baseline, clinical evidence of infection (defined as fever > 38 °C, headaches, vomiting, altered neurological status, or local symptoms) and CSF and/or CSF shunt/drains positive culture, according to the IDSA definition [1].

Brain abscess and empyema diagnoses were confirmed by radiology findings (MRI or computed tomography) and positive culture from deep surgical samples collected under sterile conditions or CSF [3].

Deep deep brain stimulator (DBS)-infections were defined according to Tabaja et al. [12]. Device exposure to the outside or sinus tract communicating with the device; deep purulent collection surrounding DBS; positive growth of microorganisms in cultures from any of the following deep intraoperative tissue or fluid surrounding DBS parts (DBS device parts or deep fluid aspirate from implantable pulse generator pocket).

In patients with healthcare-associated ventriculitis or meningitis and an external drainage device, monitoring of CSF cultures was performed routinely. In patients without external drainage devices, additional CSF cultures were performed in case of suspicion of unfavourable evolution.

Comorbidities were summarized according to modified Charlson Comorbidity Index. Characteristics of each course of vancomycin or linezolid were collected (dose, type of administration and antimicrobial combination).

Adverse events were classified according to the Common Terminology Criteria for Adverse Events (CTCAE) [13]. Serious AE corresponded to grades 3 to 5. The role of vancomycin or linezolid in AE was first assessed by the physician in charge of the patient and then confirmed by an independent evaluator through a retrospective analysis of medical records and biological data.

Outcomes

Failure of antimicrobial treatment was the first outcome of interest, defined by a composite criteria: persistence of infection (i.e. positive culture after > 72 h of antimicrobial treatment active on the isolated bacteria), relapse of infection (i.e. new infection with the same bacteria involved in the initial episode) or infection related death. Second outcome of interest was AE incidence related to linezolid or vancomycin. The maximum follow-up duration was one year after the infection.

Statistical analysis

Before any analysis, a thorough verification of missing, aberrant, or inconsistent data was conducted. After the data validation phase, the updated database was locked, and all subsequent analyses were carried out on this locked version. Continuous variables were summarized descriptively using the mean, standard deviation, median, interquartile range (IQR = p25-p75), as well as minimum and maximum values. The distribution of continuous data (whether normal or not) was assessed by examining histograms and comparing medians and means. Categorical data were presented as frequencies and percentages, with percentages calculated based on the number of patients with non-missing data (prior to imputation). Comparisons between groups were performed using Student's t-test for continuous variables (or the Wilcoxon-Mann-Whitney test, if the data did not follow a normal distribution), and the Chi-squared test for categorical variables (or Fisher's exact test, if expected cell counts were low). The primary composite endpoint was analysed using survival analysis techniques, including the log-rank test and Cox proportional hazards regression. Data were censored at treatment failure, death, or 1 year after the initial infection, whichever occurred first. The proportional hazards assumption was verified visually and with Schoenfeld residuals. For the multivariable analyses, we included treatment (linezolid or vancomycin) along with potential confounding factors (Charlson score, active neoplasia, *S. aureus* infection, intensive care unit admission, and variables associated with the outcome in the univariate analysis with a p-value lower than 0.2. Inverse probability of treatment weighting (IPTW) using a propensity score was performed to investigate the robustness of our findings. Prior to modelling, we handled missing data (< 20%) through multiple imputation using a random forest algorithm [14]. We included more variables in our propensity score than in the multivariable analysis, in an attempt to control as many of the confounding factors as possible. We included the same variables as the multivariable as well as gender, type of infection, methicillin-resistant status and combination antimicrobial treatment. Given the exploratory nature of the analyses, no correction for multiple comparisons (e.g., Bonferroni-Holm adjustment) was applied. A sensitivity analysis with an univariate model was also performed in subgroups of interest. All p-values reported are two-sided, and statistical significance was defined as $p < 0.05$. Statistical analyses were performed using RStudio (v4.2.2; R Foundation for Statistical Computing, Vienna, Austria).

Results

Study population

Between 2015 and 2023, 521 patients with *Staphylococcus* spp. CNS positive culture were screened. A total of 430 patients were excluded due to only one positive culture of CoNS ($n = 229$), age under 18 years old ($n = 149$) or no treatment with vancomycin or linezolid ($n = 52$). Overall, 91 patients were included: 51 in vancomycin group and 40 in linezolid group.

Patient's characteristics

Median age was 57 years [IQR 46–66], 49% ($n = 45$) were female, and the median BMI was 25.5 kg/m^2 [IQR 21.5–27.5]. Median Charlson Comorbidity Index score was 3 [IQR 1–4] and 59.3% ($n = 54$) were hospitalized in intensive care unit. Main reason for initial hospital admission was intra-cranial bleeding (57%, $n = 51$). All patients had healthcare associated infections. Infections were meningitis ($n = 71$; 78%), brain abscesses or empyemas ($n = 16$; 18%) and DBS infections ($n = 4$; 4.4%). Sixty-eight patients (75%) had medical devices or implant related infection. Bacteria involved were mainly *Staphylococcus epidermidis* ($n = 52$; 57%) and *Staphylococcus aureus* ($n = 30$; 33%). Methicillin-resistance was detected in 46% of infections ($n = 42$).

Vancomycin and linezolid were used as first line treatment in 93% of patients ($n = 85$). Median duration of linezolid or vancomycin treatment was 7 days [IQR 4–13]; (min-max 2–32). Overall, antimicrobial treatment duration was 21 days [IQR 14–42]. Vancomycin was administered as loading dose followed by continuous infusion in all patients, with a mean steady-state concentration in plasma of 32 mg/L (SD 11). Linezolid daily dose was 1200 mg for 88% of patients ($n = 35$) and 1800 mg for 12% ($n = 5$) of patients. Medical devices or implant were removed in 92.6% of patient (63/68). Patient, infection and treatment characteristics are summarized in Table 1.

Outcomes

Median follow-up was 183 days [IQR 29–365]. During follow-up, infection persisted in 9.8% of patients ($n = 9$), infection relapsed in 6.6% ($n = 6$) and infection caused a fatal outcome in 4.4% ($n = 4$). Two patients experiment several outcomes of interest: one patient had an infection persistence and after the end of antimicrobial treatment he had a relapse of his infection; and a second patient had infection relapse and died. Overall, treatment failure occurred in 18.6% of patients ($n = 17$) and 5.5% of patients ($n = 5$) died during follow-up (Table 2).

Survival without treatment failure

In the univariate analysis of survival without treatment failure, treatment with vancomycin (HR 3.18; 95% CI [1.03–10.79]; $p = 0.032$) and active neoplasia (HR 3.30; 95% CI [1.27–8.60]; $p = 0.02$) were associated with treatment failure (Fig. 1). Details on univariate analysis and factors included in multivariable analysis are available in Table 3. In the Cox proportional hazards regression

Table 1 Patients, infections and treatments characteristics

Variable	Total ($n=91$)	Linezolid ($n=40$)	Vancomycin ($n=51$)	*p*-value
Age (years); median [IQR]	57 [46; 66]	57 [45; 64]	59 [48; 66]	0.4
Female; n (%)	45 (49%)	23 (58%)	22 (43%)	0.3
BMI (kg/m^2); median [IQR]	25.5 [21.5; 27.5]	24.5 [21.7; 26.7]	24.9 [21.1; 28.4]	0.5
Immunodepression; n (%)	1 (1%)	0 (0%)	1 (2%)	> 0.9
Active neoplasia; n (%)	21 (23%)	8 (20%)	13 (26%)	0.6
Diabetes mellitus				0.4
No diabetes; n (%)	83 (91%)	38 (95%)	45 (88%)	-
Uncomplicated diabetes; n (%)	6 (6.6%)	1 (2.5%)	5 (9.8%)	-
Complicated diabetes; n (%)	2 (2.2%)	1 (2.5%)	1 (2%)	-
Hypertension; n (%)	34 (39%)	11 (29%)	23 (46%)	0.2
Charlson Comorbidity Index; median [IQR]	3 [1–4]	2 [1–3]	3 [2–4]	0.054
Median eGFR (ml/min/1.73m^2); median [IQR]	129 [109–171]	130 [112–168]	129 [100–174]	0.5
Initial medical condition				**0.037**
Intracranial bleeding; n (%)	51 (57%)	19 (48%)	32 (64%)	-
Tumoral; n (%)	21 (23%)	8 (20%)	13 (26%)	-
Rachidian surgery; n (%)	7 (7.8%)	6 (15%)	1 (2%)	-
Parkinson's disease; n (%)	3 (3.3%)	3 (7.5%)	0 (0%)	-
Others; n (%)	8 (8.9%)	4 (10%)	4 (8%)	-
Hospitalized in Intensive Care Unit (ICU); n (%)	54 (59.3%)	21 (52.5%)	33 (64.7%)	**0.024**
Initial infection				**0.0444**
Meningitis; n (%)	71 (78%)	31 (78%)	40 (78%)	**-**
Empyema and/or brain abscess; n (%)	16 (18%)	5 (13%)	11 (22%)	**-**
DBS infection; n (%)	4 (4.4%)	4 (10%)	0 (0%)	**-**
Hemodynamic failure; n (%)	2 (2.2%)	1 (2.5%)	1 (2.0%)	> 0.9
Staphylococcus spp. involved; n (%)				0.6
S. aureus; n (%)	30 (33%)	13 (32%)	17 (33%)	-
S. epidermidis; n (%)	52 (57%)	21 (52%)	31 (61%)	-
S. capitis; n (%)	4 (4.4%)	3 (7.5%)	1 (2%)	-
S. haemolyticus; n (%)	3 (3.3%)	2 (5%)	1 (2%)	-
S. hominis; n (%)	2 (2.2%)	1 (2.5%)	1 (2%)	-
Polymicrobial infection; n (%)	16 (18%)	11 (28%)	5 (10%)	0.06
Methicillin-resistant; n (%)	42 (46%)	17 (43%)	25 (49%)	0.7
Vancomycin MIC (mg/L); median [IQR]	1 [1–1]	1 [1–1]	1 [1–1]	0.9
Linezolid MIC (mg/L); median [IQR]	1 [1–2]	1 [1–2]	1 [1–2]	0.5
Median time between surgery of initial medical condition and infection; median [IQR]	18 [11–45]	20 [11–71]	15 [10–33]	0.3
Bloodstream infection associated; n (%)	18 (22%)	9 (26%)	9 (20%)	0.7
Implant or devices associated infection; n (%)	68 (75%)	30 (75%)	38 (75%)	> 0.9
Median CSF cell count (cell/mm^3); median [IQR]	165 [20-1800]	68 [7-1440]	735 [51-2987]	0.12
Linezolid or vancomycin treatment duration (days); median [IQR]	7 [4–13]	7 [4–14]	7 [4–11]	0.4
Overall antimicrobial treatment duration (days); median [IQR]	21 [14–42]	21 [14–42]	20 [14–42]	0.7
Associated treatment; n (%)				
No combination; n (%)	43 (47%)	19 (48%)	24 (47%)	> 0.9
Piperacilline/tazobactam; n (%)	2 (2.2%)	1 (2.5%)	1 (2%)	-
3rd -generation cephralosporins; n (%)	12 (13%)	6 (15%)	6 (12%)	-
Cefepim; n (%)	8 (8.8%)	4 (10%)	4 (7.8%)	-
Carbapenem; n (%)	26 (29%)	10 (25%)	16 (31%)	-
Surgical intervention; n (%)	77 (85%)	32 (80%)	45 (88%)	0.4
Implant/devices removal during surgery; n (%)	63 (80%)	25 (71%)	38 (86%)	0.2

Variables are expressed as percentages for dichotomous variables and as medians with interquartile range for continuous variables. In percentage calculation, the number of missing values was excluded from the denominator. Nonparametric tests were used to compare groups (chi-square, Fisher exact and Mann-Whitney U tests), as appropriate. eGFR: estimate glomerular function; DBS: Deep brain stimulator; MIC: minimal inhibitory concentration; CSF: cerebrospinal fluid

Table 2 Outcomes

Outcomes	Overall (*n* = 91)	Linezolid (*n* = 40)	Vancomycin (*n* = 51)
Treatment failure[A]	**17 (18.7%)**	**4 (10%)**	**13 (25.5%)**
Persistence of infection; n (%)	9 (9.9%)	1 (2.5%)	8 (15.7%)
Relapse of infection; n (%)	6 (6.6%)	3 (7.5%)	3 (5.9%)
Infection-related death; n (%)	4 (4.4%)	0 (0%)	4 (7.8%)
Death; n (%)	5 (5.5%)	0 (0%)	5 (9.8%)
Adverse events; n (%)	10 (11%)	1 (2.5%)	9 (17.6%)

A: Two patients experiment several outcomes of interest in vancomycin group: one patient had an infection persistence and after the end of antimicrobial treatment he had a relapse of his infection; and a second patient had infection relapse and died

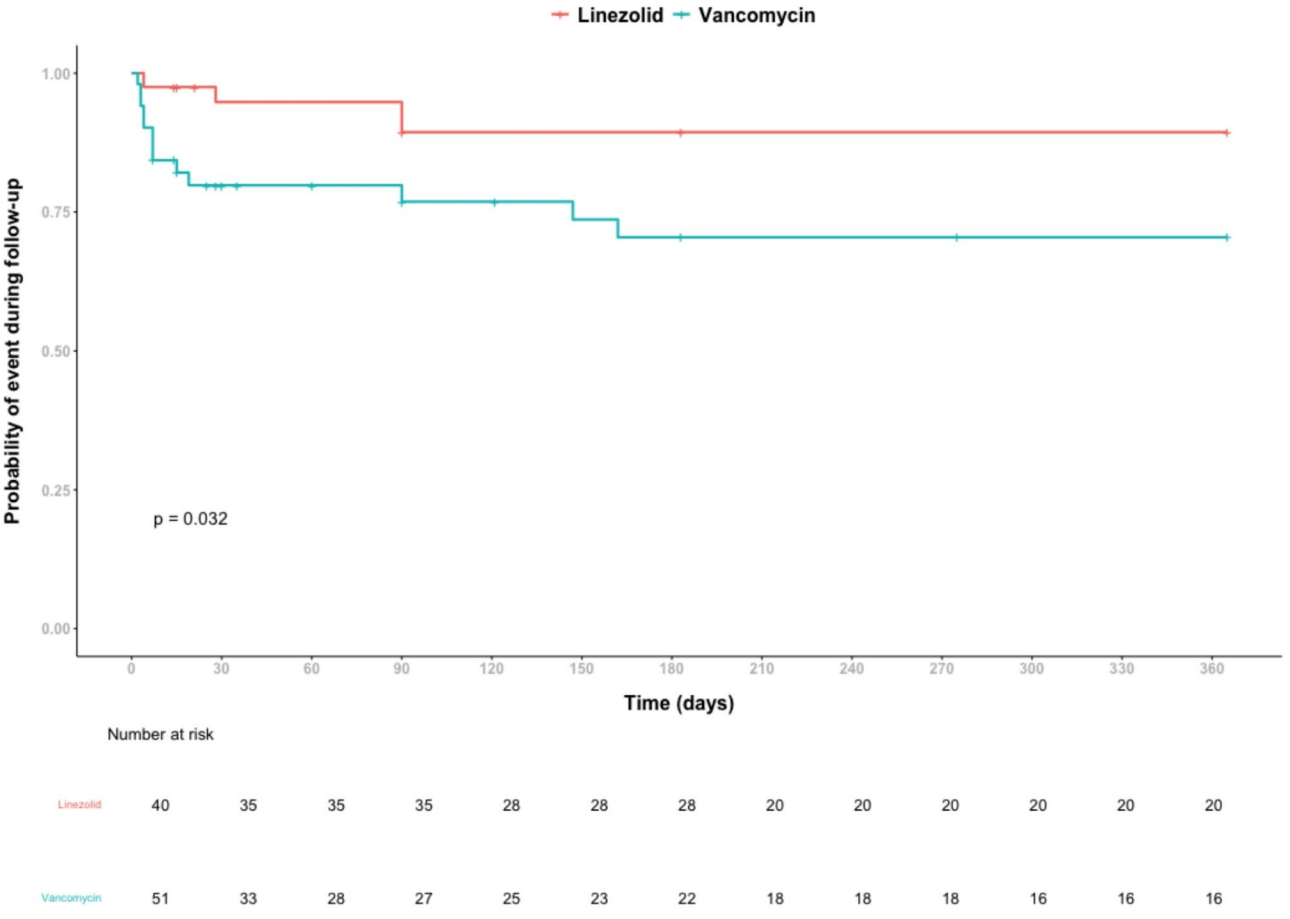

Fig. 1 Kaplan-Meier estimates for probability of survival without treatment failure. Data were censored at treatment failure, death, or 1 year after the end of antimicrobial treatment

model, vancomycin was not associated with treatment failure (aHR 2.90; 95% CI [0.93–9.30]; $p = 0.066$). Using inverse probability of treatment weighting (IPTW) based on the propensity score, vancomycin was associated with treatment failure (HR 3.28; 95% CI [1.02–10.54]; $p = 0.045$).

In univariate sensitivity analysis, treatment with vancomycin was not associated with failure in the meningitis subgroup ($N = 71$; HR 7.67; 95% CI [0.97–60.57]; $p = 0.053$), in the methicillin resistance subgroup ($N = 42$; HR 4.03; 95% CI [0.47–34.74]; $p = 0.204$); or in *S. aureus* subgroup (HR 3.95; 95% CI [0.80-19.28]; $p = 0.089$).

Adverse events

Thirteen adverse events related to vancomycin or linezolid were identified in 10 patients (11%). Twelve AE were attributable to vancomycin (acute kidney insufficiency ($n = 4$), vascular access complications ($n = 4$), hypokalaemia ($n = 1$), hyponatremia ($n = 1$), allergic reaction ($n = 1$), and white cell count decreased ($n = 1$)) and one to linezolid (platelet count decreased). Nine patients (10%) had at least one serious AE (four patients had grade III acute kidney injury, three patients grade III vascular access complication (i.e. deep vein thrombosis related to vancomycin administration *via* peripheral venous access

Table 3 Univariate and multivariate analysis of survival without treatment failure

Variable	Univariate analysis (HR [CI95])	*p*-value	Multivariate analysis (aHR [CI95])	*p*-value
Sexe				
Female	1	-	-	-
Male	1.15 [0.44–2.99]	**0.770**		
Active neoplasia				
No	1	-	1	-
Yes	3.30 [1.27–8.60]	**0.014**	4.12 [1.22-13.847]	**0.022**
Intensive care unit admission				
No	1	-	1	-
Yes	1.46 [0.54–3.97]	**0.451**	2.6 [0.86–3.02]	0.091
Age				
+ 10 years	1.16 [0.79–1.71]	**0.450**	-	-
Charlson score				
< 2	1	-	1	-
≥ 2	1.40 [0.46–4.30]	**0.556**	0.85 [0.24–3.02]	0.807
Anti-staphylococcal treatment				
Linezolid	1	-	1	-
Vancomycin	3.18 [1.03–9.79]	**0.043**	2.94 [0.93–9.30]	0.066
Bloodstream infection associated				
No	1	-	-	-
Yes	1.25 [0.41–3.85]	**0.692**		
Type on infection				
Deep-brain stimulator infection	1	-	-	-
Meningitis	0.68 [0.09–5.325]	**0.714**		
Empyema and/or abscess	1.70 [0.20–14.2]	**0.622**		
Methicillin resistance				
No	1	-	-	-
Yes	0.63 [0.23–1.70]	**0.363**		
Staphylococcus species				
Coagulase-negative staphylococci	1	-	1	-
S. aureus	2.58 [0.99–6.70]	**0.051**	2.19 [0.80–5.98]	0.127
Combination therapy with β-lactam				
No	1	-	-	-
Yes	1.11 [0.42–2.91]	**0.834**		
Implant/devices removal[A]				
No	1	-	-	-
Yes	0.43 [0.12–1.58]	**0.201**		

HR: Hazard ratio; aHR: adjusted Hazard ratio; CI: confidence interval **A**: Among patient with implant ($n = 68$)

devices), one patient had grade III allergic reaction, and one patient had grade III hypokalaemia and hyponatremia). AE occurred a median of 7 days (IQR 6–12) after vancomycin or linezolid initiation.

Discussion

To our knowledge, this is the first study comparing vancomycin and linezolid in staphylococcal-associated CNS infections. Despite the limitations due to the retrospective nature of our study, we highlight some important insights that we believe may improve treatment of patients with staphylococcal-associated CNS infections.

In this study, we report that patients treated with vancomycin had a significantly higher risk of treatment failure compared to those treated with linezolid in the IPTW analysis (HR 3.28; 95% CI [1.02–10.54]; $p = 0.045$), but not in the multivariate analysis, despite a large confidence interval (aHR 2.90; 95% CI [0.93–9.30]; $p = 0.066$), possibly due to the low statistical power of our study. A recent meta-analysis compared vancomycin and linezolid in MRSA-associated bloodstream (including endocarditis), pulmonary and skin and soft tissue infections. Linezolid was found to be more effective than vancomycin in pulmonary and skin and soft tissue infections but not in bloodstream infections [15]. To date, this is the first study comparing linezolid and vancomycin in staphylococcal-associated CNS infections. Our results suggest that linezolid could be a valuable treatment option for these infections, however, they should be interpreted with caution given the study's limitations.

CNS infections are challenging to treat because treatment success is conditioned by the CSF penetration of antimicrobials. This penetration is hindered by various barriers, including the Blood-Brain Barrier which

is the most impermeable [16]. In order to reach PK/PD objectives in CSF, high dose regimens are recommended, exposing patients to an increased risk of AE. Here we highlight that patients treated with vancomycin had a higher rate of adverse events (HR 8,42; CI 95% [2,44;29,10]; $p = 0{,}019$), compared to patients treated with linezolid. Dorazio et al. also reported a higher rate of AE in patients with skin and soft tissue infection treated with vancomycin plus clindamycin compared to linezolid [17]. On the opposite, Ju et al. reported no difference between linezolid or vancomycin in AE [15]. This may be explained by the fact that the main risk factors associated with vancomycin AE are being critically ill undergoing treatment for more than 3 to 5 days [6] and patients with CNS infections particularly filled these criteria. Moreover, some studies have reported that high vancomycin concentrations may be associated with renal toxicity, as observed in our study [7]. At last, we reported 3 preventable serious deep venous thrombosis because of administration of high doses of vancomycin *via* peripheral venous devices, which is not recommended. Regarding linezolid, we reported only one non-serious AE. Linezolid related-AE are mainly due to cumulative doses, and occurred from 10 to 14 days after treatment initiation [18], allowing physicians to initiate and step down linezolid if methicillin-susceptible staphylococci is identified or continued treatment if methicillin-resistant staphylococci is identified. However, potential thrombocytopenia induced by extended linezolid treatment should be closely monitored in patients with a recent history of brain haemorrhage and those with CSF shunts or drains, due to the potential for bleeding complications.

Our study has several limitations. First, treatment groups were small and therefore the number of unfavourable outcomes was low, reducing statistical power. Second, this was a retrospective study and reporting bias could lead to underestimate AE frequency. The third pitfall is that, due to the retrospective and observational design, patient characteristics were quite heterogeneous. Although, patients treated with vancomycin or linezolid remained comparable. Finally, no therapeutic drug monitoring was performed in either the CSF or plasma for linezolid, or in the CSF for vancomycin, preventing us from correlating treatment failure with the CSF concentrations. Vancomycin plasma concentrations were high (32 mg/L), suggesting that treatment failure was not due to underexposure.

In conclusion, patients treated with vancomycin for staphylococcal-associated CNS infection seem to have a higher risk of treatment failure and AE compared to those treated with linezolid. However, given the low statistical power and the observational nature of this study, these findings should be interpreted with caution. Further randomized clinical trials are needed to confirm these results and to better compare the efficacy of vancomycin and linezolid in these infections, including CSF exposure monitoring.

Abbreviations

CNS	Central Nervous System
CoNS	Coagulase-Negative Staphylococci
IDSA	Infectious Diseases Society of America
ESCMID	European Society of Clinical Microbiology and Infectious Disease
MRS	Methicillin-Resistant Staphylococci
CSF	Cerebrospinal Fluid
AE	Adverse Event
DBS	Deep Brain Stimulator
CTCAE	Common Terminology Criteria for Adverse Events
IQR	Interquartile Range
IPTW	Inverse Probability of Treatment Weighting

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12879-025-10834-5.

Supplementary Material 1

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None.

Author contributions
ML, CC and FX were involved in the conception of the study. LB, GC and VD provided initial data set. ML and XB performed the acquisition and analysis of data. All authors contributed to draft, revisions and approved the final manuscript.

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This work was part of our routine work.

Data availability
The data sets generated during and/or analysed during the current study are available from corresponding author on reasonable request.

Declarations

Compliance with ethics guidelines
This study was approved by the Health and Research Ethics Committee of Bordeaux (CER-BDX 2023 – 167) and was conducted in accordance with the Helsinki Declaration. The study was conducted following the MR-004 reference methodology, relating to the processing of retrospective and prospective personal data implemented in the framework of studies and evaluations in the field of health in France. Patients were informed during the collection of personal data to comply with the European Union General Data Protection Regulation (GDPR). According to MR-004 and French legislation, obtaining written consent from patients was not required. None of the patients objected to the analysis of their data for research purposes. The study also received approval from the Data Protection Officer (DPO) and the National Data Protection and Privacy Commission (CHUBX2023RE0136).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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