EAS Journal of Anaesthesiology and Critical Care
Abbreviated Key Title: EAS J Anesthesiol Crit Care
ISSN: 2663-094X (Print) & ISSN: 2663-676X (Online)
Published By East African Scholars Publisher, Kenya

OPEN ACCESS

Volume-8 | Issue-3 | May-Jun-2026 | DOI: https://doi.org/10.36349/easjacc.2026.v08i03.008

Original Research Article

Bacterial Ecology and the Impact of Probabilistic Antibiotic Therapy in Recurrent Hospital-Acquired Pneumonia Caused by Non-Fermenting Gram-Negative Bacilli in Patients on Mechanical Ventilation

Mobio N'kan Michael Paterne[1,2]*, Kouamé Koffi Isidore[1], Bouh Judith Kousseu[1], Frederic Faibis[2], Ango Privat Désiré[1], Netro Edwige Djohui[1], Gabriel Makeya[1], Allou Assoi Ahi Ange Paterne[1], Coulibaly Vatogoma[1], Eric Diomande Sogbety[1,2], Rodrick Tchoukwan[2], N'guessan Yapi Francis[1], Vivien Hong Tuan[2]

[1]Felix Houphouet-Boigny University, Faculty of Medical Sciences Abidjan, Department of Anesthesiology and Intensive Care, Ivory Coast
[2]Grand Hopital De L'est Francilien, France

Article History
Received: 12.04.2026
Accepted: 03.06.2026
Published: 11.06.2026

Journal homepage:
https://www.easpublisher.com

Quick Response Code

Abstract: ***Introduction*:** Ventilator-associated pneumonia (VAP) is one of the most common nosocomial infections in intensive care units. Non-fermenting Gram-negative bacilli (NGNB), particularly Pseudomonas aeruginosa, are frequently implicated in late-onset and recurrent cases. These infections are associated with repeated antibiotic exposure, the emergence of bacterial resistance, and high mortality. The objective of this study was to describe the bacterial ecology, the appropriateness of probabilistic antibiotic therapy, and the outcomes of patients with recurrent VAP caused by GNNB. ***Methods*:** A multicenter retrospective study was conducted in the intensive care units at the Meaux, Jossigny, and Coulommiers sites of the Grand Hôpital de l'Est Francilien. Adult patients with at least three documented episodes of BGNNF-associated PAVM between January 2021 and December 2025 were included. Clinical, microbiological, therapeutic, and clinical course characteristics were analyzed. ***Results*:** Among 293 recorded episodes of PAVM with BGNNF, 166 episodes involved 51 patients with at least three infectious episodes. The mean age was 64.5 years, and 67.5% of patients were male. The mean IGS II score was 64 and the mean Charlson score was 7.1. Most PAVMs were late-onset (87.3%). Pseudomonas aeruginosa accounted for 89.1% of isolates. Probabilistic antibiotic therapy was based primarily on piperacillin-tazobactam. It was appropriate in only 50.6% of cases. The 28-day mortality rate was 35.5%. ***Conclusion*:** Recurrent BGNNF-associated PAVM occurs in patients who are particularly critically ill and have significant comorbidities. The predominance of Pseudomonas aeruginosa and the low rate of appropriate probabilistic antibiotic therapy underscore the need to better account for the local epidemiology in order to optimize initial management.

Keywords: Recurrent PAVM – Non-Fermenting Gram-Negative Bacilli – Antibiotic Therapy.

INTRODUCTION

Ventilator-associated pneumonia (VAP) is one of the most common healthcare-associated infections in intensive care units. Despite advances in prevention and management strategies, it remains associated with a significant increase in the duration of mechanical ventilation, hospital stay, healthcare costs, and mortality [1, 2].

Non-fermenting Gram-negative bacilli (NGNB), primarily Pseudomonas aeruginosa, Acinetobacter baumannii, and Stenotrophomonas maltophilia, play a major role in the epidemiology of late-onset VAP [3, 4]. Their ability to form biofilms, persist in the hospital environment, and rapidly develop antibiotic resistance makes them particularly feared pathogens in intensive care [5].

Patients requiring prolonged mechanical ventilation constitute a high-risk population for recurrent infection. In these patients, persistent bronchial colonization, impaired respiratory defense mechanisms,

***Corresponding Author:** Mobio N'kan Michael Paterne
Felix Houphouet-Boigny University, Faculty of Medical Sciences Abidjan, Department of Anesthesiology and Intensive Care, Ivory Coast

and repeated exposure to antibiotics promote the occurrence of multiple episodes of VAP [6, 7]. These recurrences represent a major therapeutic challenge due to the gradual emergence of multidrug-resistant bacteria and the decreasing efficacy of probabilistic treatments [8].

The early initiation of appropriate probabilistic antibiotic therapy is one of the main determinants. Several recent studies have shown that inappropriate initial treatment is associated with a significant increase in mortality, duration of mechanical ventilation, and length of stay in the intensive care unit [9–11]. In this context, understanding the local bacterial ecology appears essential for optimizing empirical treatment strategies.

While numerous studies have assessed the general epidemiology of VAP, few data are available regarding patients with multiple recurrent episodes in the BGNNF. A better understanding of this population could enable the adaptation of treatment protocols and the strengthening of preventive measures.

The primary objective of this study was to describe the bacterial ecology of recurrent PAVMs caused by BGNNF in the intensive care units of the Grand Hôpital de l'Est Francilien. The secondary objectives were to evaluate the appropriateness of probabilistic antibiotic therapy, to analyze appropriate therapeutic strategies, and to study the prognosis of these patients.

PATIENTS AND METHODS

This was a retrospective, descriptive, and analytical study conducted in the intensive care units at the Meaux, Jossigny, and Coulommiers sites of the Grand Hôpital de l'Est Francilien (GHEF). Data were collected over a five-year period from January 1, 2021, to December 31, 2025.

All adult patients hospitalized in the ICU who had at least three documented episodes of non-fermenting Gram-negative bacterial VAP during their stay were included.

The following were included:

- Patients aged 18 years or older;
- Patients on invasive mechanical ventilation;
- Patients with at least three microbiologically documented episodes of non-fermenting Gram-negative bacterial VAP;
- Medical records that were usable.

Definition of Recurrences

Recurrent VAP was defined as the occurrence of at least three documented episodes of VAP in the same patient. Episodes were considered distinct when they occurred after initial clinical improvement and were associated with new microbiological evidence.

Variables Studied

The variables collected included demographic data (age, sex, body mass index), severity data (IGS II, Charlson Comorbidity Index), infectious data (number of episodes, interval between episodes, early or late onset of VAP, isolated microorganisms, antibiotic susceptibility profiles), therapeutic variables (probabilistic antibiotic therapy, appropriateness of antibiotic therapy (probabilistic antibiotic therapy, appropriateness of probabilistic antibiotic therapy, antibiotic therapy adjusted based on microbiological results), and outcome-related (duration of mechanical ventilation, length of stay in the ICU, clinical course, 28-day mortality)

Statistical Analysis

Quantitative variables were expressed as mean ± standard deviation or median with interquartile range, depending on their distribution. Qualitative variables were expressed as counts and percentages. Statistical analysis was performed using R software version 4.3.

RESULTS

General Characteristics of the Population

During the study period, 293 episodes of ventilator-associated pneumonia (VAP) caused by non-fermenting Gram-negative bacilli (NGNB) were identified in the intensive care units of the Grand Hôpital de l'Est Francilien. Of these, 166 episodes (56.7%) involved 51 patients who had at least three documented episodes of VAP during their hospitalization.

The mean age of the patients was 64.5 years. Men accounted for 67.5% of the population, representing a sex ratio of 2.1. The mean body mass index was 28.4 kg/m². The patients' initial severity was high, with a mean ISCS II score of 64. The mean Charlson comorbidity index was 7.1. The mean duration of mechanical ventilation was 24.6 days, while the mean length of stay in the ICU was 24 days.

Table I: General characteristics of the patients (n = 51)

Variable	Valeur
Average age (years)	64,5
Men	67,5 %
Average BMI (kg/m²)	28,4
Average IGS II	64

Variable	Valeur
Average Charlson score	7,1
Average duration of mechanical ventilation (days)	24,6
Average length of stay (days)	24
28-day mortality	35,5 %

Distribution of Recurrent Episodes

Among the 51 patients included: 39 patients (76.5%) experienced three episodes of PAVM; 11 patients (21.6%) experienced four episodes; 1 patient (1.9%) experienced five episodes.

The average interval between two successive episodes was approximately one week.

Microbiological characteristics

Most cases of PAVM were late-onset, accounting for 87.3% of episodes.

The bacterial profile was largely dominated by Pseudomonas aeruginosa, which was responsible for 89.1% of documented episodes. The other microorganisms isolated were Stenotrophomonas maltophilia (5.4%), Acinetobacter baumannii (4.2%), and Burkholderia spp. (1.2%).

Bacterial Susceptibility Profiles

For Pseudomonas aeruginosa, the observed susceptibility rates were:

- piperacillin: 58%;
- piperacillin-tazobactam: 59%;
- ceftazidime: 63%;
- imipenem: 72%;
- meropenem: 70%.

The new β-lactam/β-lactamase inhibitor combinations showed the best profiles:

- ceftolozane-tazobactam: 95%;
- ceftazidime-avibactam: 100%.

Stenotrophomonas maltophilia remained highly susceptible to cotrimoxazole and levofloxacin. Acinetobacter baumannii strains remained primarily susceptible to amikacin.

Table II: Bacterial Susceptibility Profiles

	Pseudomonas			Stenotrophonomas			Burkholderia			Acinetobacter		
	S	**SFP**	**R**	**S**	**SFP**	**R**	**S**	**SFP**	**R**	**S**	**SFP**	**R**
piperacilline_30mg	58	6	36	0	0	100	0	0	0	0	0	100
piperacilline_100mg	0	0	0	0	0	100	0	0	100	44	28	28
piperacilline_tazobactam_30_6mg	59	6	35	0	0	100	0	0	0	0	0	100
piperacilline_tazobactam_100_10mg	0	0	0	0	0	100	0	0	100	72	22	6
ceftazidime_10mg	63	7	30	0	0	100	0	0	100	0	0	100
ceftazidime_30mg				0	0	100	100	0	0	89	11	0
imipeneme_10mg	72	6	22	0	0	100	0		100	100	0	0
meropenème_10mg	70	7	23	0	0	100	100	0		94	6	0
ceftolozane_tazobactam_30_10mg	95	0	5	0	0	100	0	0	100	0	0	100
ceftazidime_avibactam_10_4mg	100	0	0	0	0	100	0	0	0	0	0	0
amikacine_30mg	94	2	5	0	0	100	0	0	100	94	6	0
ciprofloxacine_5mg	81	6	13	0	0	100	0	0	100	6	94	0

Probabilistic Antibiotic Therapy

Probabilistic antibiotic therapy initiated upon suspicion of VAP was based primarily on:

- piperacillin-tazobactam: 52.9%;
- Third-generation cephalosporins: 11.6%;
- Fourth-generation cephalosporins: 8.5%;
- carbapenems: 3.4%;
- Other treatment regimens: 23.6%.

The effectiveness of probabilistic antibiotic therapy was observed in only 50.6% of episodes, reflecting an initial treatment inadequacy rate of 49.4%.

Appropriate Antibiotic Therapy

After receiving microbiological results and antibiotic susceptibility testing, treatments were reevaluated and adjusted.

The most frequently used antibiotics were:

- piperacillin-tazobactam: 33.1%;
- meropenem: 24.1%;
- ceftazidime: 20.5%;
- cefepime: 10.2%;
- Other agents: 12.1%.

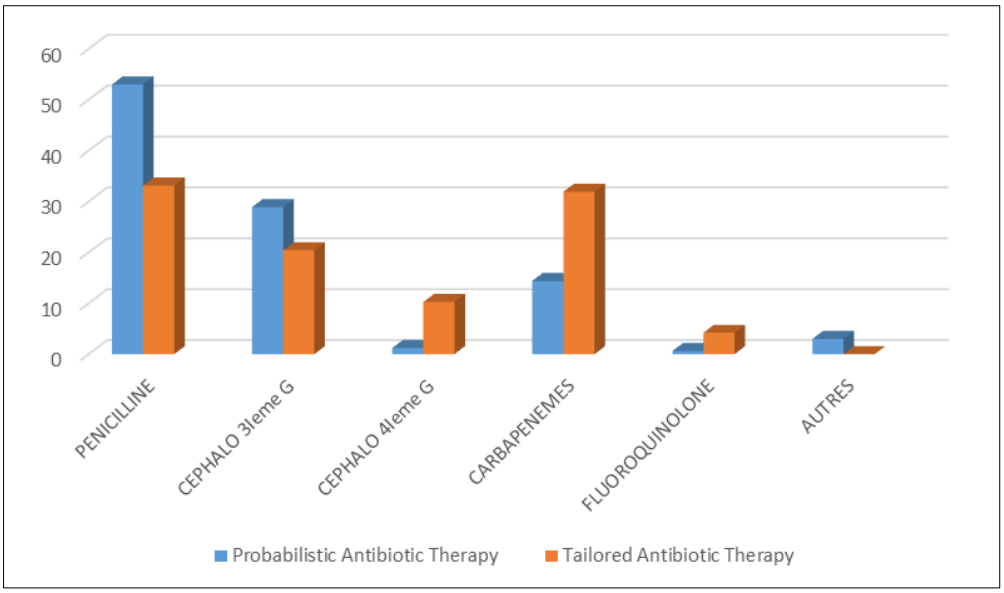

Figure 1: Probabilistic Antibiotic Therapy and Tailored Antibiotic Therapy

Clinical Course and Prognosis

The clinical course was favorable in 74.1% of episodes following therapeutic adjustment. The 28-day mortality rate was 35.5%. Deaths occurred primarily among patients requiring prolonged mechanical ventilation, with a high GCS score, and multiple comorbidities.

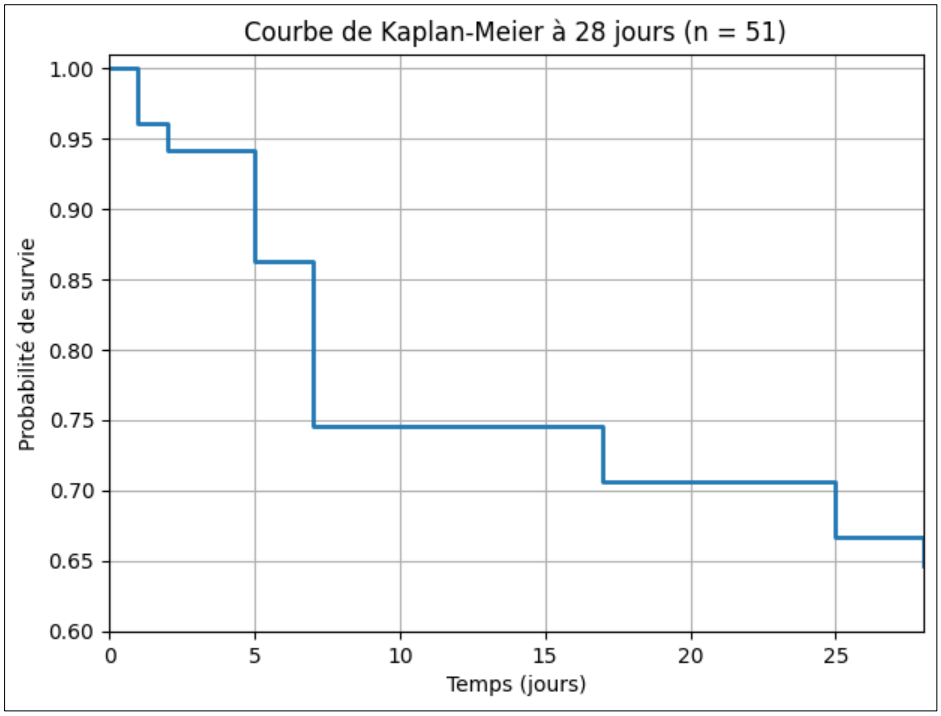

Figure 2: 28-day survival curve

DISCUSSION

Our study focused on patients with recurrent ventilator-associated pneumonia (VAP) caused by non-fermenting Gram-negative bacilli (NGNB) in the intensive care units of the Grand Hôpital de l'Est Francilien. Of the 293 episodes of VAP caused by NGMB recorded during the study period, 166 episodes involved only 51 patients who had experienced at least three infectious episodes. This finding indicates that a small number of patients account for a significant portion of the infectious burden in the ICU. Data from the literature suggest that patients with repeated episodes of VAP constitute a distinct population characterized by prolonged exposure to mechanical ventilation, a high burden of comorbidities, and significant antibiotic pressure, all of which promote recurrent infections [1–3].

In our series, patients presented a marked severity profile with a mean age of 64.5 years, a mean ISC II of 64, and a mean Charlson score of 7.1. These results are consistent with the observations of Schmidt *et al*., and Gragueb-Chatti *et al*., who report that recurrent VAP occurs predominantly in elderly, frail patients with multiple comorbidities [3, 4]. The association between initial severity, acquired immunosuppression in critically ill patients, and the occurrence of recurrent respiratory infections is now well established [5]. The high burden of comorbidities observed in our cohort could also partly explain the high mortality rate found.

The mean duration of mechanical ventilation was 24.6 days. This finding confirms the major role of prolonged ventilation in the development of recurrent PAVM. The prolonged presence of an endotracheal device promotes bacterial colonization of the lower airways, biofilm formation, and repeated microaspiration of oropharyngeal secretions [1-6]. Several studies have shown that the risk of VAP increases significantly after the fifth day of ventilation and remains high as long as invasive ventilation is maintained [1-7]. The predominance of late-onset VAP in our series (87.3%) is consistent with this finding.

From a microbiological perspective, Pseudomonas aeruginosa accounted for 89.1% of documented episodes. This proportion is higher than that generally reported in large European cohorts, where P. aeruginosa accounts for between 20% and 40% of documented VAP cases [8, 9]. This difference is likely due to the highly specific nature of our population, which consisted exclusively of patients with multiple recurrences. P. aeruginosa's ability to form biofilms, persist in the respiratory tract, and rapidly acquire resistance mechanisms contributes to its role in recurrent infections [10]. The low prevalence of Acinetobacter baumannii, Stenotrophomonas maltophilia, and Burkholderia spp. is also consistent with recent European data [8-11].

One of the key findings of our study concerns probabilistic antibiotic therapy. This was primarily based on piperacillin-tazobactam (52.9%), in accordance with current recommendations for critically ill patients at risk of NAB [12, 13]. However, the efficacy of probabilistic treatment was observed in only 50.6% of episodes. Thus, nearly one in two episodes initially received inadequate antibiotic therapy. This low rate of adequacy confirms the difficulty of effectively covering BGNNF in patients exposed to repeated infectious episodes and multiple prior courses of antibiotic therapy. Several recent studies have demonstrated that initial inadequacy of antibiotic therapy constitutes an independent risk factor for mortality in severe intensive care unit infections [14–16].

Secondary therapeutic adjustment relied primarily on piperacillin-tazobactam (33.1%), meropenem (24.1%), and ceftazidime (20.5%). This microbiological reevaluation improved the management of many patients and underscores the importance of antibiotic susceptibility testing in the therapeutic strategy. Nevertheless, the increased use of meropenem following microbiological confirmation likely reflects the frequency of the resistance profiles observed. This situation raises the issue of the risk of selecting for new resistance, particularly in Pseudomonas aeruginosa, where repeated exposure to carbapenems promotes the emergence of complex resistance mechanisms [17]. The susceptibility profiles observed in our study are particularly interesting. While susceptibility rates for piperacillin (58%), piperacillin-tazobactam (59%), and ceftazidime (63%) appeared relatively low, the new β-lactam/β-lactamase inhibitor combinations maintained excellent activity, with susceptibility rates of 95% for ceftolozane-tazobactam and 100% for ceftazidime-avibactam. These results are consistent with those of several recent European studies reporting remarkable efficacy of these new compounds against multidrug-resistant P. aeruginosa strains [18–20]. However, current guidelines emphasize the need for prudent use of these antibiotics to preserve their long-term efficacy [13-18].

The clinical course was favorable in 74.1% of episodes following therapeutic adjustment, underscoring the importance of early microbiological testing and systematic reevaluation of treatment. The 28-day mortality rate observed in our study (35.3%) confirms the severity of patients with recurrent BGNNF-associated PAVM. The concentration of deaths during the first week suggests that the prognosis is largely determined by the patients' initial severity, as evidenced by the high mean IGS II score and the high burden of comorbidities—observations also reported in recent series on recurrent PAVM [3, 4]. This mortality rate is comparable to those reported in severe respiratory infections caused by multidrug-resistant NMPB, where it generally ranges from 25% to 45% depending on patient severity, bacterial resistance profiles, and the appropriateness of the initial antibiotic therapy [8-15]. The late deaths observed after the second week may reflect the persistence of organ failure, the frailty of critically ill patients, and the impact of repeated infectious episodes on hospital outcomes [6-15].

Our study has several limitations. Its retrospective nature poses a risk of selection bias and missing data. The small sample size does not allow for a robust multivariate analysis of factors associated with mortality or recurrence. Finally, the study was conducted within a single hospital group, which may limit the generalizability of the results to other centers with different bacterial profiles.

Despite these limitations, this study provides original data on a poorly studied population of patients with recurrent BGNNF-associated VAP. Our results underscore the importance of close microbiological monitoring, regular updating of probabilistic antibiotic

therapy protocols based on local bacterial ecology, and the development of stewardship strategies to improve the appropriateness of initial therapy and limit the emergence of bacterial resistance.

CONCLUSION

Recurrent PAVM in BGNNF affects critically ill patients who are at risk of prolonged mechanical ventilation and have numerous comorbidities. These cases are predominantly caused by Pseudomonas aeruginosa and are characterized by a low rate of appropriate probabilistic antibiotic therapy. Although secondary treatment adjustments are effective in the majority of cases, mortality remains high. Improving knowledge of the local microbial ecology and optimizing probabilistic treatment strategies appear to be key challenges for improving the prognosis of these patients.

REFERENCES

1. Torres A, Niederman MS, Chastre J, et al. Guidelines for the management of hospital-acquired pneumonia (HAP)/ventilator-associated pneumonia (VAP) from the European Respiratory Society (ERS), the European Society of Intensive Care Medicine (ESICM), the European Society of Clinical Microbiology and Infectious Diseases (ESCMID), and the Latin American Thoracic Association (ALAT). The European Respiratory Journal. September 2017; 50(3):1700582. DOI: 10.1183/13993003.00582-2017. PMID: 28890434.
2. Martin-Loeches I, Povoa P, Rodríguez A., Curcio D., Suarez D., Mira JP, et al. TAVeM Study. Incidence and prognosis of ventilator-associated tracheobronchitis (TAVeM): a multicenter, prospective, observational study. Lancet Respir Med. November 2015; 3(11): 859–68. doi: 10.1016/S2213-2600(15)00326-4. Published online Oct. 22, 2015. PMID: 26472037.
3. Gragueb-Chatti I, Hyvernat H, Leone M, Agard G, Peres N, Guervilly C et al. Incidence, outcomes, and risk factors for recurrent ventilator-associated pneumonia in patients with COVID-19: a multicenter retrospective study. Journal of Clinical Medicine. 2022; 11(23):7097. https://doi.org/10.3390/jcm11237097
4. Schmidt M, Hajage D, Demoule A, Louis G, Combes A, Dres M, et al. Recurrent ventilator-associated pneumonia in critically ill patients: incidence, risk factors and outcomes. Ann Intensive Care. 2024;14(1):23.
5. Hotchkiss RS, Moldawer LL, Opal SM. Sepsis and septic shock. Nat Rev Dis Primers. 2023;9(1):21.
6. Nseir S, Martin-Loeches I, Povoa P, Metzelard M, Du Cheyron D, Lambiotte F, et al. Relationship between ventilator-associated pneumonia and mortality in COVID-19 patients: a planned ancillary analysis of the coVAPid cohort. Intensive Care Med. 2021;47(11):1205-1217.
7. Kalil AC, Metersky ML, Klompas M, Muscedere J, Sweeney DA, Palmer LB, et al. Management of adults with hospital-acquired and ventilator-associated pneumonia: 2016 Clinical Practice Guidelines by the Infectious Diseases Society of America and the American Thoracic Society. Clin Infect Dis. 2016;63(5):e61-e111.
8. Bassetti M, Giacobbe DR, Vena A, Wolff M. Management of hospital-acquired and ventilator-associated pneumonia caused by multidrug-resistant Gram-negative pathogens. Clin Microbiol Infect. 2023;29(5):593-608.
9. Timsit JF, Ruppé E, Barbier F, Tabah A, Bassetti M. How should we treat hospital-acquired and ventilator-associated pneumonia caused by multidrug-resistant Gram-negative bacteria? Intensive Care Med. 2023;49(9):1028-1042.
10. Montero MM, López-Causapé C, Cabot G, Oliver A. Evolutionary pathways toward antibiotic resistance in Pseudomonas aeruginosa and their clinical implications. Crit Care. 2023;27(1):201.
11. De Pascale G, Antonelli M. Ventilator-associated pneumonia: diagnostic challenges and therapeutic perspectives in the era of multidrug resistance. Curr Opin Crit Care. 2023;29(5):451-458.
12. Leone M, Bouadma L, Bouhemad B, Brissaud O, Dauger S, Gibot S, et al. Hospital-acquired pneumonia in intensive care units: French recommendations from the Société de Réanimation de Langue Française (SRLF) and the Société Française d'Anesthésie et de Réanimation (SFAR). Ann Intensive Care. 2023;13(1):89.
13. Tabah A, Bassetti M, Kollef MH, Zahar JR, Paiva JA, Timsit JF, et al. Antimicrobial de-escalation in critically ill patients with severe infections: current evidence and practical considerations. Intensive Care Med. 2024;50(3):311-325.
14. Kadri SS, Adjemian J, Lai YL, Spaulding AB, Ricotta E, Prevots DR, et al. Difficult-to-treat resistance in Gram-negative bacteremia and the impact of inappropriate empirical therapy on clinical outcomes. Clin Infect Dis. 2023;76(8):1345-1354.
15. Kollef MH, Torres A, Shorr AF, Martin-Loeches I, Micek ST. Antimicrobial therapy for severe hospital-acquired and ventilator-associated pneumonia: optimizing early appropriate treatment. Intensive Care Med. 2024;50(1):12-25.
16. Seymour CW, Gesten F, Prescott HC, Friedrich ME, Iwashyna TJ, Phillips GS, et al. Time to treatment and mortality during mandated emergency care for sepsis. N Engl J Med. 2017;376(23):2235-2244.
17. European Committee on Antimicrobial Susceptibility Testing (EUCAST). Breakpoint tables for interpretation of MICs and zone diameters. Version 14.0. (Sweden): EUCAST; 2024.
18. Tamma PD, Aitken SL, Bonomo RA, Mathers AJ, van Duin D, Clancy CJ. Infectious Diseases Society of America 2024 guidance on the treatment of

antimicrobial-resistant Gram-negative infections. Clin Infect Dis. 2024;78(2):e55-e99.
19. Rodríguez-Núñez O, Ripa M, Morata L, de la Calle C, Cardozo C, Fehér C, et al. Real-world effectiveness of ceftolozane-tazobactam and ceftazidime-avibactam for multidrug-resistant Pseudomonas aeruginosa infections: a multicentre European study. J Antimicrob Chemother. 2023;78(9):2289-2298.
20. Yahav D, Giske CG, Grāmatniece A, Abodakpi H, Tam VH, Leibovici L. New β-lactam–β-lactamase inhibitor combinations for the treatment of multidrug-resistant Gram-negative infections: implications for clinical practice. Clin Microbiol Infect. 2024;30(1):7-25.

Cite this article: Mobio N'kan Michael Paterne, Kouamé Koffi Isidore, Bouh Judith Kousseu, Frederic Faibis, Ango Privat Désiré, Netro Edwige Djohui, Gabriel Makeya, Allou Assoi Ahi Ange Paterne, Coulibaly Vatogoma, Eric Diomande Sogbety, Rodrick Tchoukwan, N'guessan Yapi Francis, Vivien Hong Tuan, (2026). Bacterial Ecology and the Impact of Probabilistic Antibiotic Therapy in Recurrent Hospital-Acquired Pneumonia Caused by Non-Fermenting Gram-Negative Bacilli in Patients on Mechanical Ventilation. *EAS J Anesthesiol Crit Care, 8*(3), 175-181.