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Cost-Effectiveness Analysis of Antibiotic Therapy for Community-Acquired Pneumonia at Mimika Regional Hospital, Central Papua

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ABSTRACT

Background: Community-acquired pneumonia (CAP) is a leading cause of morbidity and mortality worldwide, affecting the lower respiratory tract. It is caused by diverse pathogens, including bacteria, viruses, fungi, and chemical exposures. Antibiotics, such as ceftriaxone, are widely used for treatment. However, the high economic burden associated with CAP management necessitates a cost-effectiveness analysis to optimize treatment strategies.

Objectives: This study aimed to evaluate the cost-effectiveness of three antibiotic regimens—co-amoxiclav, meropenem + levofloxacin, and ceftriaxone—for CAP inpatients at Mimika Hospital, Indonesia, to identify the most efficient therapeutic option.

Methods: A retrospective, cross-sectional observational study was conducted using medical records of CAP patients admitted to Mimika Hospital between January and December 2021. Inclusion criteria were patients aged ≥18 years who received a single antibiotic regimen. Treatment effectiveness was assessed based on hospitalization duration (≤3 days) and physician-reported recovery. Cost-effectiveness was evaluated using the Average Cost-Effectiveness Ratio (ACER).

Results: A total of 120 pneumonia inpatients were analyzed, predominantly male (60%) and aged 26–45 years (34%). The most frequently administered antibiotic was ceftriaxone (51%), followed by co-amoxiclav (29%) and meropenem + levofloxacin (20%). Co-amoxiclav demonstrated the highest clinical effectiveness (88.57%) and the lowest median total cost (IDR 2,696,114), resulting in the lowest ACER value (IDR 2,696,114/effectiveness unit) and a dominant ICER status. In contrast, meropenem + levofloxacin showed moderate effectiveness (75%) at the highest cost (IDR 3,088,961), with an ICER of IDR 18,538.64. Ceftriaxone had the lowest effectiveness (65.57%) and the highest ACER (IDR 44.443,22), indicating poor cost-efficiency. These findings position co-amoxiclav as the most cost-effective regimen across both clinical and economic parameters.

Conclusion: Co-amoxiclav is the most cost-effective antibiotic regimen for CAP inpatients at Mimika Hospital, offering optimal therapeutic outcomes at a lower cost. These findings support its recommendation as the first-line treatment for CAP in similar healthcare settings

Keywords: ceftriaxone; co-amoxiclav; cost-effectiveness; levofloxacin; meropenem; pneumonia.

INTRODUCTION

Pneumonia is a heterogeneous group of pulmonary infections caused by various microorganisms, including bacteria, viruses, and fungi, that primarily affect the lung parenchyma. It remains a leading cause of morbidity and mortality worldwide, particularly among vulnerable populations such as children, the elderly, and immunocompromised individuals. Based on the setting in which the infection is acquired, pneumonia is broadly classified into community-acquired pneumonia (CAP) and hospital-acquired pneumonia (HAP). HAP is defined as pneumonia that develops 48 hours after a patient is hospitalized, while CAP refers to infections occurring in individuals who contract the disease in the community[1]. This classification is essential for identifying the likely etiologic pathogens and guiding appropriate treatment strategies, as CAP is frequently caused by Streptococcus pneumoniae and respiratory viruses, whereas HAP is often associated with multidrug-resistant organisms (Pseudomonas aeruginosa, Klebsiella pneumoniae, and Staphylococcus aureus). Additionally, ventilator-associated pneumonia (VAP), a subset of HAP, is a critical concern in intensive care units. Diagnostic tools such as chest X-rays and sputum cultures play a vital role in differentiating between these types of pneumonia. This distinction is particularly useful in optimizing therapeutic approaches for both hospitalized and outpatient cases [1].

Community-acquired pneumonia (CAP) is an acute respiratory infection affecting the lung parenchyma, caused by bacteria, viruses, and fungi. The most common bacterial pathogens include Streptococcus pneumoniae, Haemophilus influenzae, Staphylococcus aureus, and Gram-negative bacteria such as Enterobacteriaceae [2]. CAP is classified based on severity and the setting in which it is acquired, distinguishing it from hospital-acquired pneumonia (HAP) and ventilator-associated pneumonia (VAP) [3]. Diagnosis typically relies on clinical symptoms, radiographic imaging, and microbiological tests; however, a significant proportion of cases remain of unknown etiology due to limitations in routine diagnostic methods [4]. For hospitalized CAP patients, empirical antibiotic therapy with ceftriaxone plus azithromycin is widely recommended, particularly for moderate to severe cases[3]. Early antibiotic administration has been shown to significantly improve clinical outcomes, with symptom resolution generally occurring within 48–72 hours of treatment initiation [3,4]. However, emerging antibiotic resistance, particularly among S. pneumoniae and multidrug-resistant Gram-negative bacteria, poses significant challenges in CAP treatment, necessitating the adoption of antimicrobial stewardship programs to optimize antibiotic use and prevent resistance development [5].

Epidemiological data indicate that the prevalence of pneumonia in Indonesia increased from 1.6% in 2013 to 2.0% in 2018, reflecting a rising burden of respiratory infections [6,7]. Papua Province has consistently reported a higher prevalence than the national average, rising from 2.9% in 2013 to 3.6% in 2018 [6,7]. In 2021, Papua recorded a total of 6,374 pneumonia cases, with Mimika District having the highest burden at 3,511 cases [8]. Several factors contribute to this high incidence, including limited healthcare access, poor sanitation, high malnutrition rates, and exposure to biomass fuel smoke, all of which are established risk factors for pneumonia in low-resource settings [7]. Moreover, hospital readmission rates for pneumonia remain substantial, with 420 out of 1,000 pneumonia patients requiring rehospitalization after initial discharge, highlighting the need for improved long-term disease management strategies [7]. Given the increasing pneumonia burden, treatment strategies must not only be clinically effective but also cost-efficient to ensure optimal patient outcomes while minimizing financial strain on healthcare systems.

The economic impact of pneumonia treatment has become a crucial factor in healthcare decision-making, particularly in resource-limited settings such as Papua. Given the increasing burden of pneumonia, treatment strategies must not only be clinically effective but also cost-efficient to ensure optimal patient outcomes while minimizing financial strain on healthcare systems. A study conducted in 2018 at RSUP Dr. Hasan Sadikin Bandung assessed the cost-effectiveness of azithromycin–ceftriaxone versus azithromycin–cefotaxime combinations in treating community-acquired pneumonia (CAP) [9]. The study evaluated leukocyte reduction as an indicator of antibiotic effectiveness and found that azithromycin–cefotaxime was more cost-effective compared to azithromycin–ceftriaxone, with lower Average Cost-Effectiveness Ratios (ACERs) and greater cost savings in both payer and healthcare perspectives [9].

Cost-effectiveness analysis (CEA) is a fundamental method in health economics, providing a structured framework to evaluate the trade-offs between the costs and benefits of treatment options. It has been widely adopted to inform health policy decisions, pricing strategies, and reimbursement frameworks [10]. CEA employs incremental cost-effectiveness ratio (ICER) calculations, which compare the additional cost per unit of health gain—often measured in quality-adjusted life-years (QALYs [10]. Despite its significance, data on the cost-effectiveness of commonly used antibiotics such as ceftriaxone, meropenem, levofloxacin, and co-amoxiclav in Papua remains limited. Given the high prevalence of pneumonia in the region, this study aims to assess the effectiveness and cost-effectiveness of antibiotic therapy for CAP patients at Mimika regional Hospital. The findings are expected to provide critical insights into optimizing antibiotic selection and improving resource allocation in high-burden settings.

METHODS

Study design

The present study employed an observational, descriptive research design under a quantitative methodology. A cross-sectional approach with retrospective data collection was utilized, drawing on secondary data from hospital medical records. While basic cost information was available in the medical records, it lacked the detail required for a comprehensive analysis. To address this, additional verification and clarification of cost-related data were conducted in collaboration with the hospital's finance and administrative departments, particularly the cashier unit.

Population and samples

The study population comprised medical records of patients diagnosed with community-acquired pneumonia (CAP) who were treated at Mimika General Hospital in 2021. Participants were selected using purposive sampling from the total population. Inclusion criteria included patients aged 18 years or older who received a single antibiotic regimen during hospitalization. The antibiotics administered belonged to classes commonly used for CAP treatment, including β-lactams (e.g., co-amoxiclav), cephalosporins (e.g., ceftriaxone, cefotaxime), fluoroquinolones (e.g., levofloxacin), and macrolides (e.g., azithromycin). Exclusion criteria included unreadable or incomplete medical records, deceased patients, those with co-diagnoses of other infections, patients discharged upon personal request, and those with documented antibiotic resistance.

Data collection

Assessment of Antibiotic Effectiveness

The assessment of effective treatment was based on a Length of Stay (LOS) parameter of ≤3 days, combined with the physician's discharge decision reflecting clinical recovery or improvement, and consistency in the type of antibiotic administered throughout hospitalization. The LOS threshold of three days was adopted to reflect early clinical improvement and is supported by actual data from this study, where some patients—regardless of whether they received co-amoxiclav, meropenem + levofloxacin, or ceftriaxone—were discharged within three days based on the attending physician's evaluation. Previous studies have also identified LOS as a reliable indicator for assessing treatment effectiveness in hospitalized patients [3,11,12]. Furthermore, the clinical efficacy of antibiotic therapy can be evaluated through the achievement of clinical stability within 48 to 72 hours after treatment initiation. Clinical stability is typically defined by several criteria, including: resolution of fever for at least 24 hours, heart rate ≤100 beats per minute, respiratory rate ≤24 breaths per minute, systolic blood pressure ≥90 mmHg, and oxygen saturation ≥90% [13].

Cost

The cost analysis conducted in this study encompassed direct medical expenditures, which encompassed antibiotic treatment, administration, and clinical procedures. The expenses mentioned were obtained from the viewpoint of the hospital and reflect the charges invoiced to the individuals for the services provided during their medical care.

Cost-Effectiveness Analysis: ACER and ICER

Average Cost-Effectiveness Ratio (ACER) [10,14]

$$\text{ACER} = \frac{\text{Total Cost of the Intervention}}{\text{Total Effectiveness of the Intervention}}$$

The Average Cost-Effectiveness Ratio (ACER) is used to measure the average cost per unit of health outcome achieved by a single intervention. It is calculated by dividing the total cost of the intervention by the total effectiveness (e.g., number of recovered patients or quality-adjusted life years gained).

Incremental Cost-Effectiveness Ratio (ICER) [10,14]

$$\text{ICER} = \frac{(\text{Cost of Intervention A} - \text{Cost of Intervention B})}{(\text{Effectiveness of Intervention A} - \text{Effectiveness of Intervention B})}$$

The Incremental Cost-Effectiveness Ratio (ICER) is used to compare two interventions. It measures the additional cost required to gain one additional unit of effectiveness when switching from one intervention to another. ICER is particularly useful in determining whether the additional benefit of a new treatment justifies its additional cost

Table I. Characteristics of Subjects

Patients Characteristic		N (%)
Ages	>60th	33 (28)
	48th-60th	37 (31)
	26th-45th	41 (34)
	18th-25th	9 (8)
Gender	Male	72 (60)
	Female	48 (40)
Antibiotics Treatment	Ceftriaxone	61 (51)
	Meropenem+Levofloxacin	24 (20)
	Co-amoxiclav	35 (29)

Our study employs the utilization of ACER and ICER as metrics for assessing the relative cost-effectiveness of different therapeutic interventions. The ACER metric is utilized to assess the cost of healthcare by dividing the overall program cost by the clinical result, thereby measuring efficiency. On the other hand, ICER is employed to determine the magnitude of the incremental cost associated with each unit of cost effectiveness improvement [15].

RESULTS AND DISCUSSION

The present study evaluated the cost-effectiveness of three antibiotic regimens—ceftriaxone, meropenem + levofloxacin, and co-amoxiclav—in the treatment of hospitalized patients with community-acquired pneumonia. Key parameters assessed included patient characteristics, clinical effectiveness, total treatment cost, and pharmacoeconomic indicators such as ACER and ICER. The findings revealed notable differences in both clinical outcomes and cost-efficiency across the antibiotic groups, providing important insights to inform local treatment protocols and healthcare resource allocation.

Characteristics of participants displays in Table 1. Sociodemographic characteristics are critical factors contributing to vulnerability and clinical outcomes in pneumonia. In our study, participants were predominantly male (60%), with 65% falling within the productive to elderly age range (26–60 years). This finding aligns with several studies indicating that males tend to have a higher incidence of pneumonia. Jang et al. (2020) reported that elderly male patients post-hip fracture exhibited a higher incidence of pneumonia (16.39%) compared to females (9.29%), along with a greater risk of mortality within 30 days to one-year post-hospitalization [16]. Furthermore, a study by Kuo et al. (2020) demonstrated that male gender and younger age were significant risk factors for severe pneumonia in children and adolescents with cerebral palsy [17]. These findings underscore the role of gender as both a biological and behavioral factor across all age groups.

Age is another major determinant across diverse populations. A study by Dang et al. (2014) found that age ≥75 years and functional dependence were strongly associated with recurrent pneumonia post-hospitalization, with a recurrence rate of 9% over five years, and the risk was even higher in the elderly population [18]. Although the majority of participants in our study were under 60 years of age, the proportion of elderly participants (>60 years) remained significant (28%), highlighting the need for targeted attention to this group for relapse prevention and complication management. The consistency of these findings is further supported by the Global Burden of Disease (GBD) 2019 report, which identified lower respiratory infections (including pneumonia) as a leading cause of disability-adjusted life years (DALYs) in children under 10 years and the elderly [19].

In the context of Indonesia, particularly concerning vulnerable age groups, studies on toddlers—a high-risk population—have shown that age and immunization status significantly contribute to pneumonia incidence, while the influence of gender was not statistically significant [20,21]. Nevertheless, the high proportion of males in our study warrants further investigation as a potential indicator of access disparities or biological risk factors associated with the disease. This is supported by a study by Roux et al. (2015) in South Africa, which identified male infants, children with malnutrition, and maternal smoking exposure as significant risk factors for pneumonia in the first year of life [22].

Table II. Cost and Effectiveness of Antibiotics

Antibiotics	Median Total Cost (Rp)	Effectiveness (%)
Ceftriaxone	2.914.142	65,57
Meropenem+ Levofloxacin	3.088.961	75
Co-amoxiclav	2.696.114	88,57

Beyond individual characteristics, treatment approaches also significantly influence pneumonia outcomes. In our study, the most frequently prescribed antibiotic regimen was ceftriaxone (51%), followed by a combination of meropenem + levofloxacin (20%) and co-amoxiclav (29%). This antibiotic selection reflects the clinical pattern of severe pneumonia, particularly in hospitalized patients. A study by Blanco et al. (2021) in Spain revealed that most patients with SARS-CoV-2-related pneumonia were hospitalized for an average of 7 days, with symptoms such as cough, dyspnea, and fatigue persisting even after discharge [23]. This underscores the importance of follow-up care and appropriate initial empirical therapy. Meanwhile, national and global trends indicate that the use of broad-spectrum antibiotics such as meropenem requires strict monitoring. Sogaard et al. (2014), in a 15-year national cohort study in Denmark, observed an increase in pneumonia hospitalizations, particularly among the elderly and patients with comorbidities, despite a persistently high 30-day mortality rate (13%) [24]. This suggests that antibiotic use alone is insufficient, and preventive measures and early evaluation remain crucial. Overall, comparisons with previous studies reinforce the conclusion that sociodemographic factors and initial therapeutic approaches significantly influence pneumonia outcomes. Tailoring management strategies based on local profiles and patient characteristics, as demonstrated in the context of Mimika, Papua, is key to reducing pneumonia-related morbidity and mortality.

Cost-effectiveness analysis of antibiotics is a crucial component in decision-making for pneumonia therapy, particularly in resource-limited settings such as Mimika, Papua. Based on the data presented in Table 2, co-amoxiclav demonstrated the most optimal outcomes, with the highest effectiveness (88.57%) and the lowest median cost (IDR 2,696,114). In contrast, the combination of meropenem + levofloxacin showed moderate effectiveness (75%) but incurred the highest cost (IDR 3,088,961), while ceftriaxone exhibited the lowest effectiveness (65.57%) with intermediate cost (IDR 2,914,142). These findings indicate that co-amoxiclav is the most cost-effective therapeutic option for hospitalized pneumonia patients in our study population. These results are consistent with a study by Laelasari et al. (2023), which reported that although ceftriaxone is widely used, its clinical effectiveness is suboptimal due to prolonged hospital stays and failure to achieve target respiratory rates, coupled with higher costs compared to cefotaxime [25]. This underscores the importance of prioritizing actual clinical effectiveness over prescribing preferences. Further support comes from Saha et al. (2017), who demonstrated that beta-lactam antibiotics, such as co-amoxiclav, are both effective and cost-efficient for pediatric pneumonia therapy. Although their study focused on children, the implications for cost efficiency remain broadly applicable [26].

The effectiveness of the meropenem + levofloxacin combination is also supported by Chytra et al. (2012), who reported high success rates with meropenem therapy in critically ill patients, particularly when administered via continuous infusion [27]. This aligns with the moderate effectiveness observed in our study and reinforces its use in severe pneumonia cases. Similarly, Park et al. (2019) found that combining meropenem with colistin improved survival rates in patients with carbapenem-resistant Acinetobacter baumannii bacteremia, further validating the clinical potential of meropenem in severe infections [28]. However, the use of broad-spectrum antibiotics such as meropenem must be approached with caution due to the risk of antimicrobial resistance. In a systematic review by Zhen et al. (2019), resistance among ESKAPE pathogens—Enterococcus spp., Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa, and Escherichia coli—was shown to significantly increase hospital economic burdens and reduce therapeutic effectiveness [29]. Infections caused by these bacteria often prolong hospital stays and elevate the risk of treatment failure, particularly when antibiotic selection is not guided by local resistance profiles. In conclusion, co-amoxiclav is the most cost-effective antibiotic therapy for community-acquired pneumonia in our study population. Meanwhile, the meropenem + levofloxacin combination remains a rational choice for severe pneumonia, despite its higher cost burden. Ceftriaxone, although commonly used, requires reevaluation of its effectiveness in local contexts, as it demonstrated the lowest outcomes in this study. Antibiotic selection should be evidence-based, incorporating clinical effectiveness and local pharmacoeconomic evaluations to ensure therapeutic efficiency and the sustainability of healthcare systems.

Table III. Cost-Effectiveness Analysis (ACER)

Antibiotics	ACER (Rp/%effectivity)
Ceftriaxone	44.443,22
Meropenem + Levofloxacin	41.186,15
Co-amoxiclav	30.440,48

Table IV. Cost-Effectiveness Analysis (ICER)

Antibiotics	Total Cost Median (Rp)	Base Effectiveness (%)	ACER (Rp)	WTP (Rp)
Ceftriaxone			Reference	
Meropenem + Levofloxacin	174.819,36	9,43	Need ICER Calculation	18.538,64
Co-amoxiclav	-218.027,93	23	Dominant	-9479,28

The evaluation of cost-effectiveness using the Average Cost-Effectiveness Ratio (ACER) approach describes the absolute efficiency of each antibiotic in the treatment of community-acquired pneumonia. Based on Table III, co-amoxiclav demonstrated the lowest ACER value (IDR 2,696,114 per effectiveness unit), followed by meropenem + levofloxacin (IDR 3,088,961), while ceftriaxone had the highest ACER value (IDR 44.443,22). A lower ACER value indicates better cost efficiency in achieving effective clinical outcomes. These findings align with the results of a study by Purba et al. (2019), which reported that culture-based therapy (CBT), enabling the use of antibiotics such as co-amoxiclav, yields higher cost efficiency compared to empirical therapy. CBT not only reduces hospitalization costs but also improves clinical outcomes in hospitalized pneumonia patients in Indonesia [30]. Similarly, Smith et al. (2013) demonstrated that a procalcitonin-guided antibiotic strategy reduces the duration of antibiotic use and achieves cost savings without compromising therapeutic effectiveness [31]. The role of co-amoxiclav as an efficient therapy is further supported by microbiological sensitivity data from Acharya et al. (2020), which reported high sensitivity to co-amoxiclav against Streptococcus pneumoniae and Haemophilus influenzae, the two primary pathogens of community-acquired pneumonia. This confirms that the clinical effectiveness of co-amoxiclav is not only economically advantageous but also aligned with local microbial profiles [32]. Conversely, the high ACER value of ceftriaxone reflects its low-cost efficiency, a finding also reported in a study by Bendixen et al. (2004). The study highlighted that non-adherence to antibiotic selection guidelines, including the unjustified use of broad-spectrum antibiotics, can lead to increased treatment failure rates and higher healthcare costs [33].

The Incremental Cost-Effectiveness Ratio (ICER) analysis provides a comparative evaluation of the additional cost required to achieve increased effectiveness relative to a reference therapy. In Table IV, ceftriaxone—the standard first-line treatment—was used as the comparator. The analysis revealed that co-amoxiclav is a dominant therapy, demonstrating both higher effectiveness (23%) and lower cost, with a negative ICER value of -IDR 218,028, indicating that no further ICER calculation is necessary. According to pharmacoeconomic principles, a therapy that is more effective and less expensive is considered optimal, reinforcing the role of co-amoxiclav as a primary treatment option. In contrast, meropenem + levofloxacin showed a moderate increase in effectiveness (9.43%) but required an additional cost of IDR 174,819, resulting in an ICER of IDR 18,538.64. This implies that each 1% improvement in effectiveness incurs an additional cost of this amount. Consequently, this regimen falls into Category I, where higher cost accompanies higher efficiency, necessitating stronger clinical justification for its use. These findings are consistent with Uda et al. (2019), who emphasized the value of de-escalation strategies in pneumonia treatment, with co-amoxiclav emerging as a cost-effective empirical therapy [34]. Conversely, as highlighted by Ott et al. (2002), initial treatment failure is a key driver of increased hospitalization costs, underscoring the importance of reserving more expensive regimens like meropenem + levofloxacin for high-risk or severe cases. From a policy perspective, the ICER results support the promotion of co-amoxiclav as the first-line therapy in resource-limited settings, while higher-cost options should be reserved for clinically justified scenarios, taking into account national willingness-to-pay (WTP) thresholds [35].

One of the strengths of our study lies in its comprehensive analytical approach, which not only describes the characteristics of pneumonia patients at Mimika Regional Hospital but also evaluates clinical effectiveness and cost efficiency by comparing several antibiotic regimens using pharmacoeconomic methods, such as the ACER and ICER. This analysis provides valuable insights for policymakers and healthcare workers in determining rational and cost-effective therapeutic choices, particularly in resource-limited settings with restricted healthcare access. Additionally, direct data collection from referral hospitals in remote areas offers important local context for understanding clinical practices in the field. However, this study has limitations, as it was conducted in a single hospital with a limited sample size and did not include laboratory analysis of antibiotic resistance patterns. Therefore, the findings should be interpreted with caution and validated through further research with broader geographic coverage and a more in-depth laboratory approach.

CONCLUSION

Co-amoxiclav has proven to be the most cost-effective antibiotic for community-acquired pneumonia at Mimika District Hospital, demonstrating the highest clinical effectiveness (88.57%), the lowest Average Cost-Effectiveness Ratio (ACER) (IDR 2,696,114), and a dominant position in the Incremental Cost-Effectiveness Ratio (ICER) analysis. The meropenem + levofloxacin combination may be considered for severe cases but is associated with a higher cost burden. In contrast, ceftriaxone exhibited the lowest effectiveness and cost-efficiency, necessitating a critical reevaluation of its role in local treatment protocols. Antibiotic selection should be guided by pharmacoeconomic evidence, local antimicrobial resistance profiles, and patient-specific clinical conditions. Further validation through multicenter studies is recommended to support the integration of co-amoxiclav into national pneumonia treatment guidelines.

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STATEMENT OF ETHICS

Ethical Approval Number 14741/UN4.14.1/TP.01.02/2022 from Healthy Research Ethics Committee, Faculty of Public Health, Hasanuddin University approved at 8 November 2022.

STATEMENT ON AI USE IN MANUSCRIPT PREPARATION

The authors declare that artificial intelligence (AI), specifically ChatGPT, DeepSeek, and Scite, was used in a limited capacity to assist in sentence structuring, grammar checking, manuscript editing, and preliminary literature searches. However, the primary roles in research design, data analysis, result interpretation, and the writing of scientific content were entirely carried out by the authors. All authors have thoroughly read, reviewed, and ensured the accuracy and integrity of the manuscript's content. The full responsibility for the scientific content and integrity of this manuscript remains solely with the authors.

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