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Cost-Effectiveness of Antibiotics for Geriatric Pneumonia in an Indonesian Regional Hospital

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ABSTRACT

Cost-effectiveness of commonly used antibiotic regimens in geriatric inpatients with pneumonia was evaluated through a retrospective review of medical records at Pelabuhan Ratu Regional General Hospital (January–December 2021). Eligible patients were aged ≥60 years with a length of stay ≥2 days; 100 of 700 records met inclusion. Direct medical costs—antibiotics, inpatient care, and other medications—were obtained from hospital tariffs and expressed in Indonesian Rupiah (Rp). Clinical effectiveness at discharge was defined as temperature ≤37,8 °C, respiratory rate <30/min, and leukocyte count ≤10.500/µL. The most frequently used single agents were ceftriaxone (32%), levofloxacin (26%), azithromycin (14%), and cefixime (2%); common substitutions included ceftriaxone–azithromycin (9%) and levofloxacin–ceftriaxone (6%). The lowest average cost-effectiveness ratio (ACER) occurred with cefixime (Rp 581.209). In incremental analysis, levofloxacin–cefixime compared with ceftriaxone monotherapy yielded an incremental cost-effectiveness ratio (ICER) of Rp 117.786 per 1% additional effectiveness, supporting ceftriaxone as the more cost-effective option. Overall, cefixime was most economical by ACER, whereas ceftriaxone monotherapy was preferred by ICER.

Keywords:
Antibiotics; Cost-effectiveness; Geriatrics; Pharmacoeconomics; Pneumonia

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1. Introduction

In Indonesia, according to the 2018 Basic Health Research (Riskesdas), the prevalence of pneumonia among all age groups reached 2.21%, with the 44-64 age group at 2.5%, the 64-74 age group at 3.0%, and those aged 75 and above at 2.9%. Based on JKN statistical data from 2014-2018, pneumonia cases with primary diagnosis codes ICD X J180 and J189 amounted to 271,496 hospital admissions, with total claim costs under the INACBGs code J-4-16-I (mild pneumonia & mild whooping cough) totaling approximately Rp 769,000,000,000 (seven hundred and sixty-nine billion rupiah). Meanwhile, in 2015, the global mortality rate from lower respiratory tract infections decreased compared to 2000, from 55.7 to 43.4 deaths per 100,000 population. Despite this, lower respiratory tract infections remained the third leading cause of death, accounting for 5.7% of all deaths and a cumulative percentage of 32.2%. In the United States, pneumonia is the leading cause of hospitalization. Each year, approximately one million patients are hospitalized due to pneumonia, with a mortality rate of 50,000 cases annually [1].

Pneumonia is an acute infection of the lung parenchyma, particularly the alveoli, which disrupts gas exchange and is commonly caused by bacteria, viruses, or fungi. The main pathogenic bacteria responsible for pneumonia include Streptococcus pneumoniae and Mycoplasma pneumoniae, while viral agents include adenovirus, rhinovirus, influenza virus, respiratory syncytial virus (RSV), and parainfluenza virus. Additionally, pneumonia can be indirectly influenced by other coexisting medical conditions, as well as exposure to chemicals or physical trauma to the respiratory system [2].

In Indonesia, pneumonia in the elderly is a significant public health concern. Data from the 2018 Riskesdas survey indicate a high prevalence of pneumonia in the 65–74 and >75 age groups, based on both diagnosis and symptoms (Riskesdas Nasional, 2018). Similarly, globally, geriatric patients with Community-Acquired Pneumonia (CAP) face a higher risk of complications, treatment failure, prolonged hospitalization, and increased mortality [3]. This condition not only affects the quality of life of patients but also imposes a substantial economic burden on healthcare systems worldwide.

Antibiotics are a category of drugs that are commonly used worldwide to treat various bacterial infections. According to the latest pneumonia guidelines from the National Institute for Health and Care Excellence (NICE) in 2025, the treatment for inpatients with community-acquired pneumonia is Amoxicillin, Doxycycline, Clarithromycin, Erythromycin, Co-amoxiclav, Levofloxacin, Cefalexin, Co-trimoxazole, Piperacillin with Tazobactam, Ceftazidime, Ceftriaxone, Cefuroxime, Meropenem, Ceftazidime with Avibactam, Vancomycin, Teicoplanin, and Linezolid [4]. Appropriate antibiotic administration will yield significant benefits, including improved clinical outcomes, reduced toxicity, cost-effectiveness, and reduced antibiotic resistance. Conversely, inappropriate antibiotic therapy will have adverse effects, such as the development of bacterial resistance to antibiotics [5].

Cost-effectiveness analysis (CEA) is a pharmacoeconomic evaluation method used to select and evaluate the most efficient health programmes or treatments among various options with similar treatments. In conducting a cost-effectiveness analysis, data on treatment and parameters or outcomes that measure the effectiveness of therapy are required. *The average cost-effectiveness ratio* (ACER) is a measure that calculates the ratio of costs in currency units per specific clinical outcome by dividing the total cost of the programme/alternative therapy by the clinical outcome achieved. *The incremental cost-effectiveness ratio (*ICER) is the ratio between the costs of two alternatives with a difference in effectiveness between the alternatives [6].

Various studies on the *cost-effectiveness* analysis of antibiotics in the treatment of pneumonia show differences in terms of effectiveness and cost. For example, a study by Rahardjoputro et al. (2024) in Surakarta compared the use of levofloxacin and ceftriaxone as empirical antibiotics for pneumonia. Although levofloxacin is more expensive, ceftriaxone proved to be more effective with a therapy success rate of 93.33% and more cost-effective with a reduction in cost per patient of IDR 87,172 compared to levofloxacin [7]. On the other hand, research by Farida et al. (2022) also showed that levofloxacin provided better clinical results, but at a higher cost compared to ceftriaxone or a combination of ceftriaxone + azithromycin [8]. Research by Nandini et al. (2025) in India highlights the importance of transitioning from intravenous to oral antibiotic therapy to reduce hospital costs, even though intravenous therapy provides more significant clinical improvement [9]. A study by Wahid et al. (2021) at Dewi Sri Karawang Hospital, Indonesia, analysed the cost-effectiveness of antibiotic therapy in hospitalised pneumonia patients. The results showed that five commonly prescribed antibiotic

therapies for the treatment of pneumonia in patients over 45 years of age using a combination of ceftriaxone 1 g i.v + azithromycin 500 mg p.o had better cost-effectiveness, with a Cost-Effectiveness Ratio (CER) of £23,108 per day, with an average treatment duration of 2.67 days, compared to other antibiotic therapies such as levofloxacin and Levocin [10], [11]. Overall, despite variations in research results, the majority of studies suggest that ceftriaxone provides greater benefits in terms of cost and effectiveness compared to levofloxacin, especially in the context of lower hospitalisation costs. However, the effectiveness of treatment also depends heavily on factors such as local bacterial resistance and patient condition.

Therefore, considering the diverse use of antibiotics, other medications, length of hospitalisation, and parameters in hospitalised pneumonia patients, it is necessary to research to determine the effectiveness of antibiotics in terms of cost-effectiveness and clinical outcomes with or without antibiotic combinations in geriatric pneumonia patients hospitalised in hospitals, where geriatric pneumonia patients are patients with a high incidence of disease, especially during the Covid-19 pandemic when this data was analysed.

2. Methods

Study design and setting

This retrospective descriptive chart review was conducted at Pelabuhan Ratu Regional General Hospital (Indonesia). Index admissions spanned 1 January–31 December 2021 (overlapping the COVID-19 period), and data were extracted from hospital information systems between 17 July and 1 September 2023. All included patients were covered by Indonesia's National Health Insurance (JKN; administered by BPJS Kesehatan).

Participants and eligibility

Inclusion criteria were: age ≥60 years, inpatient diagnosis of pneumonia, receipt of systemic antibiotics, and length of stay ≥2 days; exclusion criteria were concurrent non-pneumonia infections and incomplete medical records. Clinical management in this setting followed national and international guidance for adult pneumonia [2],[3].

Sampling and sample size

Consecutive sampling was applied to all eligible cases during the study period. From a hospital population of 700 pneumonia admissions, 100 geriatric inpatients met inclusion criteria and were analysed. Reasons for exclusion were logged.

Data sources and variables

Data were abstracted from inpatient medical records and the hospital information system: demographics (sex, age), comorbidities, vital signs, laboratory values, route/type/duration of antibiotic therapy (single or substitutions), other medications, and direct medical costs. Patient identifiers were used only for linkage and were not retained in the analytic dataset.

Effectiveness definition

Clinical effectiveness at discharge required meeting all of the following: temperature ≤37.8 °C, respiratory rate <30/min, and leukocyte count ≤10,500/μL, consistent with guideline-based clinical stability criteria [2],[3]. Criteria used locally for IV-to-oral switch included clinical stability (e.g., afebrile, haemodynamically stable), heart rate <100 bpm, and ability to tolerate oral intake [4].

Costing perspective and horizon

Costs were evaluated from the provider (hospital) perspective over the inpatient episode; discounting was not applied given the short time horizon. Direct medical costs

comprised antibiotic acquisition costs (from pharmacy/finance units), inpatient (ward) charges (from the administration unit), and other medication costs. All costs are presented in Indonesian Rupiah (Rp), 2021 tariffs, consistent with prior Indonesian economic evaluations in pneumonia [5].

Economic analysis

The average cost-effectiveness ratio (ACER) was calculated as total direct medical cost / effectiveness (%). The incremental cost-effectiveness ratio (ICER) was calculated as $(C_B - C_A)/(E_B - E_A)$, using ceftriaxone monotherapy as the reference comparator, in line with local cost-effectiveness practice[6]. Regimens with higher cost and lower effectiveness than the comparator were classified as dominated and were not considered further in incremental analyses [7]. Small-sample groups were interpreted cautiously.

Statistical analysis

Categorical variables were summarised as n (%); continuous variables as mean ± SD or median (IQR), as appropriate. Analyses used complete-case data; no imputation was performed.

Ethical Approval

Administrative permission was obtained from the hospital. The study received approval from the Immanuel Health Institute Research Ethics Committee, Bandung (No. 037/KEPK/IKI/V/2023), with a waiver of informed consent due to the retrospective design and use of de-identified data.

3. Results and Discussion

Patient characteristics

Data were extracted at Pelabuhan Ratu Regional General Hospital between 17 July and 1 September 2023. The target population comprised 700 geriatric pneumonia admissions, of which 100 met the inclusion criteria and formed the analytic sample.

Table I. Patient characteristics (N = 100)

A. Sex

Sex	**n**	%
Male	65	65%
Female	35	35%
Total	100	100%

B. Age group

Age (years)	**n**	%
60–70	77	77%
71–80	20	20%
81–90	3	3%
Total	100	100%

C. Comorbidities*

Category	**n**	%
None	22	22%
Hypertension	49	49%
Heart failure	17	17%
Diabetes	12	12%
Total	100	100%

D. Ward class and length of stay (LOS)

Ward class	**LOS (days)**	**n**	%
Class 1	3–9	15	15%

Class 2	4–9	9	9%
Class 3	3–9	76	76%
Total	—	100	100%

Among the 100 inpatients (all covered by JKN, Indonesia's National Health Insurance), 65 were male (65%) and 35 were female (35%), indicating a higher proportion of male cases. The age distribution was 60–70 years (77%), 71–80 years (20%), and 81–90 years (3%). These proportions are consistent with prior Indonesian reports showing a greater pneumonia burden in older adults; age-related declines in respiratory anatomy and physiology likely contribute to susceptibility in this group [11].

Hypertension was the most frequent comorbidity (49%), followed by heart failure (17%) and diabetes (12%). As noted by Sumandar (2021), hypertension may coexist with pathophysiological changes relevant to pneumonia outcomes (e.g., gas-exchange impairment and haemodynamic stress), underscoring the clinical complexity of these patients [12].

Most admissions were treated in Class 3 wards (76%) with a length of stay of 3–9 days (Class 1: 15%, 3–9 days; Class 2: 9%, 4–9 days). Under the hospital tariff structure, total costs typically increase with longer stays and higher ward class; therefore, identifying cost-effective antibiotic regimens is pertinent to managing resource use in this population.

Types of Antibiotics

The treatment of pneumonia involves diagnosing the patient and administering antibiotics to eliminate the microorganisms suspected of causing the infection. Based on **Table 2**, the categories of drugs administered to geriatric pneumonia patients treated at Pelabuhan Ratu Regional General Hospital from January to December 2021 can be identified. The antibiotics used included third-generation cephalosporins (ceftriaxone, cefixime), carbapenems (meropenem), quinolones (levofloxacin), and macrolides (azithromycin).

Table 2. Percentage of antibiotic use in hospitalised pneumonia patients at Pelabuhan Ratu Regional General Hospital, January–December 2021

Regimen type	Antibiotic regimen	Patients (n)	Percentage
Single	Levofloxacin (IV)	26	26%
	Azithromycin (oral)	14	14%
	Ceftriaxone (IV)	32	32%
	Cefixime (oral)	2	2%
Substitution (change during hospitalisation)	Ceftriaxone (IV) – Azithromycin (oral)	9	9%
	Levofloxacin (IV) – Cefixime (oral)	3	3%
	Ceftriaxone (IV) – Cefixime (oral)	5	5%
	Levofloxacin (IV) – Meropenem (IV)	3	3%
	Levofloxacin (IV) – Ceftriaxone (IV)	6	6%
Total		**100**	**100%**

In this study, the use of third-generation cephalosporin antibiotics for the treatment of pneumonia in elderly patients at Pelabuhan Ratu Regional General Hospital accounted for 34% of total antibiotic use. The antibiotics used were ceftriaxone and cefixime.

Ceftriaxone is the most commonly prescribed antibiotic for elderly patients with pneumonia treated at Pelabuhan Ratu Regional General Hospital. Ceftriaxone is a third-generation cephalosporin antibiotic with broad effectiveness against gram-negative and gram-positive bacteria. It is commonly used in the treatment of bacterial pneumonia. Ceftriaxone is widely used because it is the drug of choice in the treatment of pneumonia. Ceftriaxone has a longer half-life than other cephalosporins, so it only needs to be administered once or twice a day.

The criteria for switching from intravenous therapy to oral antibiotics are as follows: the patient must be able to take medication orally, have a heart rate <100 beats per minute, blood pressure above 90 mmHg, respiratory rate below 25 breaths per minute, recovery of cognitive function to pre-illness levels, body temperature below 37.8 °C, and a white blood cell count of 10,500/µL or less [13]. To change the method of antibiotic administration from intravenous to oral, the patient's condition must be considered, such as the severity, response to treatment, and the patient's ability to swallow antibiotics orally. Thus, oral administration of antibiotics must have the same effectiveness as intravenous administration [14].

Replacing antibiotics administered intravenously in patients with pneumonia who were initially given intravenous antibiotics with the same route of administration is done to ensure rational and effective treatment. This may be influenced by several factors, including the patient's clinical improvement, the results of bacterial sensitivity tests to antibiotics, and recommendations for rational antibiotic use.

Other Medications Used Besides Antibiotics

The primary treatment for pneumonia is the administration of antibiotics, which aim to inhibit or eliminate the bacteria causing pneumonia. However, patients may be given treatments other than antibiotics. Additional treatments in this study were used to address patient complaints during their hospitalisation at Pelabuhan Ratu Regional General Hospital.

Table 3. Use of other medications among geriatric pneumonia inpatients, Pelabuhan Ratu Regional General Hospital (January–December 2021)

No.	Drug name	Percentage
1	Paracetamol	93%
2	Salbutamol	84%
3	Acetylcysteine	78%
4	Methylprednisolone	63%
5	Candesartan	45%
6	Ondansetron	40%

Based on **Table 3** shows that the most commonly used medication for geriatric pneumonia patients admitted to Pelabuhan Ratu Regional General Hospital is paracetamol (93%), as most hospitalised pneumonia patients are admitted with a body temperature above 37.8°C. The second most commonly administered medication is salbutamol (84%). Paracetamol (acetaminophen) has become the primary medication of choice for managing fever in pneumonia patients, including those caused by COVID-19

infection. The main benefit of paracetamol is its ability to relieve fever and reduce pain, which greatly helps to improve patient comfort. Caragea et al. (2022) explained that in pneumonia patients, especially those caused by the SARS-CoV-2 virus, paracetamol is used to reduce fever symptoms without causing significant side effects at therapeutic doses [15]. Furthermore, although paracetamol is effective in managing symptoms, Chidiac et al. (2023) also note that caution is needed in using this drug, as overdose, although rare, can cause serious liver damage, especially in patients who take large amounts of this drug or in combination with other drugs. Therefore, although paracetamol is beneficial for managing pneumonia symptoms, the appropriate dosage must still be observed to avoid harmful side effects [16].

Cost-Effectiveness Analysis (CEA)

Cost of Antibiotic Use

Antibiotic costs were determined by reviewing each patient's medical records, noting their antibiotic use, and calculating the costs based on the prices at Pelabuhan Ratu Regional General Hospital, as shown in **Table 4**.

Table 4. Average cost of antibiotic use in geriatric pneumonia inpatients at Pelabuhan Ratu Regional General Hospital from January to December 2021

Regimen type	Antibiotic regimen	n	Average antibiotic cost (Rp)
Single	Levofloxacin	26	Rp 270,000.00
	Azithromycin	14	Rp 115,348.57
	Ceftriaxone	32	Rp 197,788.00
	Cefixime	2	Rp 49,200.00
Substitution (change during hospitalization)	Ceftriaxone–Azithromycin	9	Rp 219,780.00
	Levofloxacin–Cefixime	3	Rp 236,400.00
	Ceftriaxone–Cefixime	5	Rp 170,200.00
	Levofloxacin–Meropenem	3	Rp 925,000.00
	Levofloxacin–Ceftriaxone	6	Rp 347,800.00†

Research shows that levofloxacin-meropenem antibiotics have an average price of Rp. 925,000, making them the most expensive antibiotics compared to other antibiotics. Conversely, cefixime antibiotics have the lowest average cost because they are affordable, with an average price of Rp. 49,200. This can have an impact on the costs associated with antibiotic use, namely the length of hospitalisation. Research by Choudhari et al. (2024) provides insights into the use of cefixime in the treatment of acute respiratory tract infections (ARIs), particularly pneumonia. In a survey involving 247 doctors, it was found that cefixime is widely used due to its broad effectiveness against various bacteria that cause infections, including *Streptococcus pneumoniae, Haemophilus influenzae,* and *Moraxella catarrhalis.* Doctors chose cefixime mainly because of its broad-spectrum activity (46.75%) and good safety profile (27.87%). Cefixime was also chosen for its ease of once-daily dosing and affordability, making it the drug of choice in the

management of pneumonia and other respiratory tract infections. Overall, 92.73% of doctors rated cefixime as a safe and reliable antibiotic choice in ARTI therapy [17].

Inpatient Costs

Inpatient expenses include the cost of patient room maintenance and consultations with doctors, which are determined based on the level of service received. The treatment classes for pneumonia patients at Pelabuhan Ratu Regional General Hospital are divided into three types, namely class 1, class 2, and class 3. Based on the results of **Table 5**, the highest average hospitalisation cost was in the levofloxacin–cefixime group at 1,180,666.67. This was because patients in the therapy group utilised the treatment room and underwent prolonged hospitalisation, namely, more than 4 days.

Table 5. Average hospitalization cost by regimen, January–December 2021

Regimen type	Antibiotic regimen	Average hospitalization cost (Rp)
Single	Levofloxacin	Rp 603,115.38
	Azithromycin	Rp 811,642.86
	Ceftriaxone	Rp 511,000.00
	Cefixime	Rp 515,000.00
Substitution (change during hospitalization)	Ceftriaxone–Azithromycin	Rp 688,666.67
	Levofloxacin–Cefixime	Rp 1,180,666.67
	Ceftriaxone–Cefixime	Rp 584,600.00
	Levofloxacin–Meropenem	Rp 381,666.67
	Levofloxacin–Ceftriaxone	Rp 840,833.33

The length of hospitalisation in patients receiving Levofloxacin-Cefixime therapy is consistent with research by Syaffa et al. (2025) on antibiotic use patterns in pneumonia patients at Hospital P, showing that antibiotic combinations such as Levofloxacin and Cefixime are often used in more complex cases of pneumonia, including polymicrobial infections or pneumonia with unclear aetiology. This combination provides a broad spectrum to treat various bacteria that may be involved in the infection. This is particularly important in patients with more severe conditions, as mixed infections require intensive therapy to avoid further complications and shorten the length of hospitalisation. Syaffa et al. note that the selection of appropriate antibiotics, such as the combination of Levofloxacin and Cefixime, can improve treatment effectiveness, although ultimately, patients who require antibiotic combinations often experience a more severe disease course and require longer treatment times [18].

Total Treatment Costs

Total expenditure includes all costs incurred by the patient from admission to the hospital, during treatment, until discharge from the hospital. Total costs are calculated by adding up all costs incurred by patients during their hospitalisation that

are directly related to the treatment they received. Components included in the overall costs are costs related to antibiotics, additional medications, and hospitalisation. The percentage of each cost in each treatment group is determined by dividing each cost in each group by the total cost per treatment group and multiplying by 100%.

Table 6. Average total costs for geriatric pneumonia inpatients at Pelabuhan Ratu Regional General Hospital, January–December 2021

Regimen type	Antibiotic regimen	Antibiotic cost (Rp)	Inpatient cost (Rp)	Other medication cost (Rp)	Total cost (Rp)
Single	Levofloxacin	Rp 270,000.00	Rp 603,115.38	Rp 95,728.62	Rp 968,844.00
	Azithromycin	Rp 115,348.57	Rp 811,642.86	Rp 68,204.00	Rp 995,195.43
	Ceftriaxone	Rp 197,788.00	Rp 511,000.00	Rp 73,997.22	Rp 782,785.22
	Cefixime	Rp 49,200.00	Rp 515,000.00	Rp 17,009.00	Rp 581,209.00
Substitution (change during hospitalization)	Ceftriaxone–Azithromycin	Rp 219,780.00	Rp 688,666.67	Rp 62,588.00	Rp 971,034.67
	Levofloxacin–Cefixime	Rp 236,400.00	Rp 1,180,666.67	Rp 101,882.00	Rp 1,518,948.67
	Levofloxacin–Meropenem	Rp 925,000.00	Rp 381,666.67	Rp 67,189.33	Rp 1,373,856.00
	Levofloxacin–Ceftriaxone	Rp 347,800.00	Rp 840,833.33	Rp 70,808.83	Rp 1,259,442.16
	Ceftriaxone–Cefixime	Rp 170,200.00	Rp 584,600.00	Rp 40,486.00	Rp 795,286.00

Notes:
Totals are recalculated as: Antibiotic + Inpatient + Other medication; rounded to two decimals

The results of the calculations in Table 6 show that the highest total costs occurred with the antibiotics levofloxacin-cefixime, which were influenced by the average cost of hospital care. This is due to the longer hospitalisation period for patients in this antibiotic group, ranging from 5 to 6 days, and patients being placed in class 1 and 3 rooms. Thus, hospital costs tend to increase with longer treatment, including the length of treatment and the type of treatment room used. Research by Syaffa et al. (2025) revealed that in pneumonia patients with mixed infections or pneumonia with unknown causes, the use of antibiotic combinations such as Levofloxacin and Cefixime is the primary choice. This combination therapy is chosen because of its broad spectrum, effective in treating various types of pathogens, both Gram-positive and Gram-negative bacteria, which are often found in polymicrobial infections. The administration of this combination of antibiotics is very important for patients with more serious conditions, as mixed infections are usually more difficult to treat and require a more aggressive approach. Syaffa and colleagues emphasise that although this combination of antibiotics is effective in treating more complex infections, patients who require this type of therapy often experience a more severe course of disease, resulting in increased length of hospital stay and higher intensity of care [18].

The selection of the appropriate antibiotic, especially for severe cases of pneumonia, plays an important role in speeding up patient recovery and preventing

further complications. Levofloxacin, a fluoroquinolone antibiotic, is effective against various pathogens, including atypical bacteria that often cause severe pneumonia. Meanwhile, cefixime, a third-generation cephalosporin antibiotic, is effective in treating Gram-negative bacteria commonly found in polymicrobial infections. In such cases, appropriate antibiotic therapy not only improves recovery rates but also helps reduce treatment failure rates and shorten the duration of treatment, although in reality, patients still require a longer hospital stay.

Levofloxacin and Cefixime as intensive therapy to treat polymicrobial infections and accelerate infection resolution. The treatment profile for pneumonia in a study by Purnamawati et al. (2023) shows that this combination is commonly used in severe cases requiring further treatment [19]. A study by Wulandari et al (2019) at Dr. Ario Wirawan Salatiga Lung Hospital indicated that combination antibiotic therapy, such as Ceftriaxone and Cefixime, correlates with longer hospital stays and increased costs as patient conditions become more complex [20]. In line with a cost-effectiveness study by Prasetyo et al. (2024) at Dr. Iskak Tulungagung Regional General Hospital, it was found that although Levofloxacin and Ceftriaxone are both clinically effective, the use of antibiotic combinations is often associated with higher hospitalisation costs due to longer treatment duration and the need for intensive monitoring [21].

Effectiveness of Antibiotic Therapy

The effectiveness of antibiotic therapy in this study was assessed by laboratory tests at the end of the hospitalisation period, with a white blood cell count of less than 10,500/µL. Based on clinical improvement, with a normal temperature ≤ 37.8 °C and a respiratory rate < 30, the patient was considered cured and allowed to be discharged. Furthermore, the efficacy of each antibiotic variant was assessed and determined to range between 83.33–100%

Table 7. Clinical effectiveness of antibiotic regimens in geriatric pneumonia inpatients, Pelabuhan Ratu Regional General Hospital (January–December 2021)

Regimen type	Antibiotic regimen	n	Effective, n (%)
Single	Levofloxacin (IV)	26	24 (92.31%)
	Azithromycin (oral)	14	14 (100.00%)
	Ceftriaxone (IV)	32	30 (93.75%)
	Cefixime (oral)	2	2 (100.00%)
Substitution (change during hospitalization)	Ceftriaxone (IV) – Azithromycin (oral)	9	9 (100.00%)
	Levofloxacin (IV) – Cefixime (oral)	3	3 (100.00%)
	Levofloxacin (IV) – Meropenem (IV)	3	3 (100.00%)
	Levofloxacin (IV) – Ceftriaxone (IV)	6	5 (83.33%)
	Ceftriaxone (IV) – Cefixime (oral)	5	5 (100.00%)

Based on **Table 7**, the percentage of antibiotic therapy effectiveness in pneumonia patients treated at Pelabuhan Ratu Regional General Hospital from January–December 2021, the patients who achieved 100% therapeutic efficacy were those treated with azithromycin, cefixime, ceftriaxone-azithromycin, levofloxacin-cefixime, levofloxacin-meropenem. This effectiveness is influenced by the severity of the

pneumonia suffered, or indeed based on the condition of pneumonia patients admitted to the hospital, which will affect the duration of drug administration. The calculated effectiveness values are then used in the ACER and ICER calculations.

Effectiveness Analysis (ACER)

Cost-effectiveness analysis compares alternatives with the same objective by relating costs to health effects; programmes with lower cost for a given effect are prioritised [22]. In this study, the average cost-effectiveness ratio (ACER) was calculated as ACER = C / (E/100), where C is the direct medical cost (sum of antibiotic, inpatient, and other medication costs) and E is clinical effectiveness at discharge (%) [23]. The results are summarised in Table 8.

The results are summarised in **Table 8**, cefixime recorded the lowest ACER (Rp 581,209), reflecting 100% effectiveness at the lowest total direct cost among single-agent regimens. Ceftriaxone had a lower ACER (Rp 834,971) than azithromycin (Rp 995,195) and levofloxacin (Rp 1,049,555). Among substitution regimens, ceftriaxone–cefixime yielded an ACER of Rp 795,286, while combinations involving levofloxacin generally produced higher ACERs (e.g., levofloxacin–ceftriaxone Rp 1,511,391; levofloxacin–cefixime Rp 1,518,949).

Table 8. Calculation of ACER Values for Antibiotic Therapy

Regimen type	Antibiotic regimen	Direct medical cost, C (Rp)	Effectiveness, E (%)	ACER = C / E (Rp)
Single	Levofloxacin	Rp 968,844.00	92.31	Rp 1,049,554.76
	Azithromycin	Rp 995,195.43	100.00	Rp 995,195.43
	Ceftriaxone	Rp 782,785.22	93.75	Rp 834,970.90
	Cefixime	Rp 581,209.00	100.00	Rp 581,209.00
Substitution (change during hospitalization)	Ceftriaxone–Azithromycin	Rp 971,034.67	100.00	Rp 971,034.67
	Ceftriaxone–Cefixime	Rp 795,286.00	100.00	Rp 795,286.00
	Levofloxacin–Meropenem	Rp 1,373,856.00	100.00	Rp 1,373,856.00
	Levofloxacin–Ceftriaxone	Rp 1,259,442.16	83.33	**Rp 1,511,391.05**
	Levofloxacin–Cefixime	Rp 1,518,948.67	100.00	**Rp 1,518,948.67**

These ACER rankings should be interpreted with caution because several regimen groups had small sample sizes (e.g., cefixime n=2), which can inflate observed effectiveness (100%) and drive ACER to equal the cost. Moreover, ACER compares each regimen to a null baseline; therefore, incremental comparisons (ICER) against a clinically relevant comparator (ceftriaxone monotherapy in this analysis) provide a more reliable basis for decision-making than ACER alone [22].

Prior literature provides supportive but not definitive context. Citraningtyas et al. (2019) reported lower ACER for cefixime versus cefotaxime in diarrhoea management

(different indication), while Aminudin et al. (2025) reported that cefixime use in adult pneumonia was associated with reduced length of stay [24],[25]. Differences in indication, case-mix, and study design limit direct comparability, but these findings are consistent with the cost-efficient profile of cefixime observed here.

Incremental Cost-Effectiveness Ratio (ICER)

Category placement on the cost–effectiveness grid is based on total direct medical cost and clinical effectiveness, not on ACER values [22]. For pairwise comparisons, the ICER is defined as

$$\text{ICER} = \frac{\Delta\text{Cost}}{\Delta\text{Effectiveness}} = \frac{C_B - C_A}{E_B - E_A},$$

and is only meaningful when the incremental effectiveness ($E_B - E_A$) is non-zero; regimens with higher cost and lower effectiveness than the comparator are dominated and excluded from incremental analysis [22],[23].

Using ceftriaxone monotherapy as the reference comparator (effectiveness 93.75%; total cost Rp 782,785.22), alternatives were positioned on the A–I grid (**Table 9**). Levofloxacin and levofloxacin–ceftriaxone fall in cell C (higher cost, lower effectiveness) and are dominated. Cefixime falls in cell G (higher effectiveness, lower cost; "dominant"), but this finding is based on a very small group (n = 2) and should be interpreted cautiously. Regimens with higher effectiveness and higher cost—azithromycin, ceftriaxone–azithromycin, ceftriaxone–cefixime, levofloxacin–meropenem, and levofloxacin–cefixime—fall in cell I; these can be assessed with ICER when a willingness-to-pay per 1% effectiveness gain is considered [22],[23].

Table 9. Cost–effectiveness grid (A–I) relative to ceftriaxone monotherapy (reference)

Effectiveness \ Cost	**Low cost**	**Same cost**	**High cost**
Lower effectiveness	A —	B —	C Levofloxacin; Levofloxacin–Ceftriaxone *(dominated)*
Equivalent effectiveness	D —	E —	F —
Higher effectiveness	G Cefixime *(dominant; n = 2)*	H —	I Azithromycin; Ceftriaxone–Azithromycin; Ceftriaxone–Cefixime; Levofloxacin–Meropenem; Levofloxacin–Cefixime

In this analysis, levofloxacin–cefixime (cell I) was selected for an illustrative ICER against ceftriaxone (reference). The incremental cost was Rp 736,164 with an incremental effectiveness of 6.25%, yielding an ICER of Rp 117,786 per 1% additional effectiveness (**Table 10**). Given the modest gain in effectiveness and the large incremental cost, ceftriaxone remains the more cost-effective option in this setting [22],[23].

Table 10. ICER for levofloxacin–cefixime (substitution) vs ceftriaxone (single)

Regimen	Direct medical cost (Rp)	Effectiveness (%)	ΔCost (Rp)	ΔEffectiveness (%)	ICER (Rp per 1% effectiveness)
Levofloxacin–Cefixime	1,518,949	100.00	736,164	6.25	**117,786**
Ceftriaxone (reference)	782,785	93.75	—	—	—

Levofloxacin-Cefixime requires an additional cost of Rp 117,786 to achieve a 1% increase in effectiveness compared to Ceftriaxone. This indicates that Ceftriaxone is more cost-efficient for each small increase in effectiveness compared to Levofloxacin-Cefixime. Cefixime shows a lower ACER value and appears to be cheaper, but Ceftriaxone was chosen as a more cost-effective therapy due to its lower additional cost for a smaller increase in effectiveness. This is also reinforced by the ICER calculation involving Levofloxacin-Cefixime and Ceftriaxone, which shows that Ceftriaxone provides almost equivalent effectiveness at a lower cost, making it the optimal choice in the context of managing the costs of treating pneumonia in geriatric patients. Thus, the selection of Ceftriaxone as a more cost-effective therapy is based on the ICER calculation, which shows that the additional cost for each higher unit of effectiveness is lower in Ceftriaxone compared to Levofloxacin-Cefixime, which makes Ceftriaxone the best choice in the management of pneumonia in geriatric patients.

This study has several limitations. First, the retrospective design limits the ability to establish clear causal relationships and may introduce bias in data collection, as well as other uncontrolled factors such as variations in patient management. Second, this study was conducted at Palabuhan Ratu Regional General Hospital, which limits the generalizability of the findings to a broader population. Third, the context of the COVID-19 pandemic presents additional challenges in assessing the effectiveness of antibiotic therapy, particularly in geriatric patients with pneumonia. The COVID-19 pandemic may have influenced treatment choices, length of hospitalization, and the severity of patients' conditions. Patients treated during the pandemic may have had different clinical characteristics, including more comorbidities or higher disease severity, which could affect treatment outcomes. However, one of the main limitations of this study is that the COVID-19 status of the patients was not distinguished, making it unclear whether the patients analyzed had pneumonia caused by COVID-19 or by bacterial infections.

4. Conclusion

Cefixime had the lowest ACER, but this reflects a very small group and ACER alone should not guide decisions. In the incremental comparison, levofloxacin–cefixime versus ceftriaxone monotherapy yielded an ICER of Rp 117,786 per 1% additional effectiveness, indicating that ceftriaxone achieves comparable effectiveness at lower incremental cost. Accordingly, ceftriaxone monotherapy is the most cost-effective regimen for geriatric pneumonia in this hospital setting.

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Conflicts of Interest:

The author declares that there are no conflicts of interest in this research.

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