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Economic Evaluation of Prudent Antibiotic Usage Campaigns: Enhancing Healthcare Quality and Reducing Costs

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background and Objective: Irrational use of antibiotics is a major cause of antibiotic resistance and increases healthcare costs. Promoting the prudent use of antibiotics in hospitals is an essential effort to improve the quality of antibiotic use among healthcare workers. This study aims to evaluate the quality and cost analysis of antibiotic use in surgical cases at RSND Semarang before and after the campaign for prudent antibiotic use.
Methods: This study uses a quasi-experimental design with a one-group pre-test and post-test. The sample consisted of 86 patient medical records of surgical cases that met the inclusion and exclusion criteria at RSND. Data on the quality of antibiotic use were obtained from the medical records and analyzed by the RSND PPRA team using the Van Meer and Gyssens criteria. Data

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analysis was performed using the Chi-square test, and a cost analysis was conducted before and after the campaign for prudent antibiotic use.
Results: The study found a significant difference in the quality and cost of antibiotic use in surgical cases at RSND Semarang before and after the campaign. Out of 44 medical records and 76 antibiotic prescriptions, the most frequently prescribed antibiotics were Ceftriaxone, Cefazolin, and Cefadroxil. The majority of antibiotics were categorized under Category V (no indication), accounting for 47.3%. The cost of antibiotic use in inappropriate categories (I-IV) was 1,003,630 IDR, while for Category V it was 497,606 IDR. The cost of appropriate antibiotic use (Category 0) was the lowest, at 332,653 IDR.
Conclusion: The use of antibiotics without proper indication and inappropriately contributes the highest costs, with the most expensive being the inappropriate use of antibiotics. This highlights the importance of prudent antibiotic management to reduce unnecessary healthcare expenses and combat antibiotic resistance.

Keywords: Cost analysis; antibiotic; prudent use campaign; quality assessment.

1. INTRODUCTION

Antibiotics are drugs that can inhibit the growth or kill microorganisms. Their use is intended for the prevention and treatment of microbial infections (Uddin et al., 2021). Unwise use of antibiotics is frequently encountered in both developed and developing countries. Hospitals are the primary sites where antibiotics are most extensively used. In hospitals, where there is a high volume of antibiotic usage, bacterial resistance to several antibiotics is common and poses a major challenge in patient care (Ramdan et al., 2024). Infections caused by resistant bacteria can lead to prolonged hospital stays, increased treatment costs, and even higher mortality rates . A study conducted in Switzerland in 2010 found that 9-46% of hospitalized patients received inappropriate therapeutic and prophylactic antibiotics. This prevalence study revealed that 37% of therapeutic antibiotic use and 16.6% of prophylactic antibiotic use were not in accordance with proper indications (Cusini et al., 2010).

Asian countries have been reported to have a higher prevalence of irrational antibiotic prophylaxis use (48%-100%) compared to developed countries (23.4%-55.2%). This is evident from a study conducted in Malaysia in 2012, which showed that 66.3% of prophylactic antibiotic use and 42% of therapeutic antibiotic use were not in accordance with proper indications (Lim MunKit et al., 2015). The administration of prophylactic antibiotics to patients undergoing surgical procedures aims to prevent surgical site infections (SSIs), which can prolong hospital stays, double readmission rates, and triple treatment costs (Dhole et al., 2023).

In hospitals, 98% of patients undergoing surgical procedures are given prophylactic antibiotics, but only 68% of their use aligns with established protocols. This inappropriate use can result in a 3-4 fold increase in therapeutic failure (Chung et al., 2022). Antibiotics should be administered with clear justification, as the growing development of bacterial resistance is closely associated with their usage. Therefore, prophylactic antibiotic use should be minimized, and the spectrum of activity of the drugs used should be as narrow as possible. Despite the established principles of prophylactic antibiotic use in surgery, inappropriate usage still persists (World Health Organization, 2011; Hadi et al., 2010).

Based on the explanation above, the researchers deemed it necessary to conduct a study on the quality and cost analysis of antibiotic use in surgical cases at Diponegoro National Hospital (RSND) before and after the campaign for the prudent use of antibiotics.

2. METHODOLOGY

This study was conducted at the Diponegoro National Hospital (RSND) using medical records from the surgery and obstetrics-gynecology departments, focusing on cases receiving antibiotic treatment. The study design was a quasi-experimental two-group pre-test and post-test approach combined with cost analysis. The sample size consisted of 172 surgical case medical records from Diponegoro National Hospital, comprising 43 medical records for the pre-campaign phase and 43 medical records for the post-campaign phase. The study evaluated the quality of antibiotic use based on the Van der Meer-Gyssens criteria and conducted a cost analysis (Putra et al., 2021).

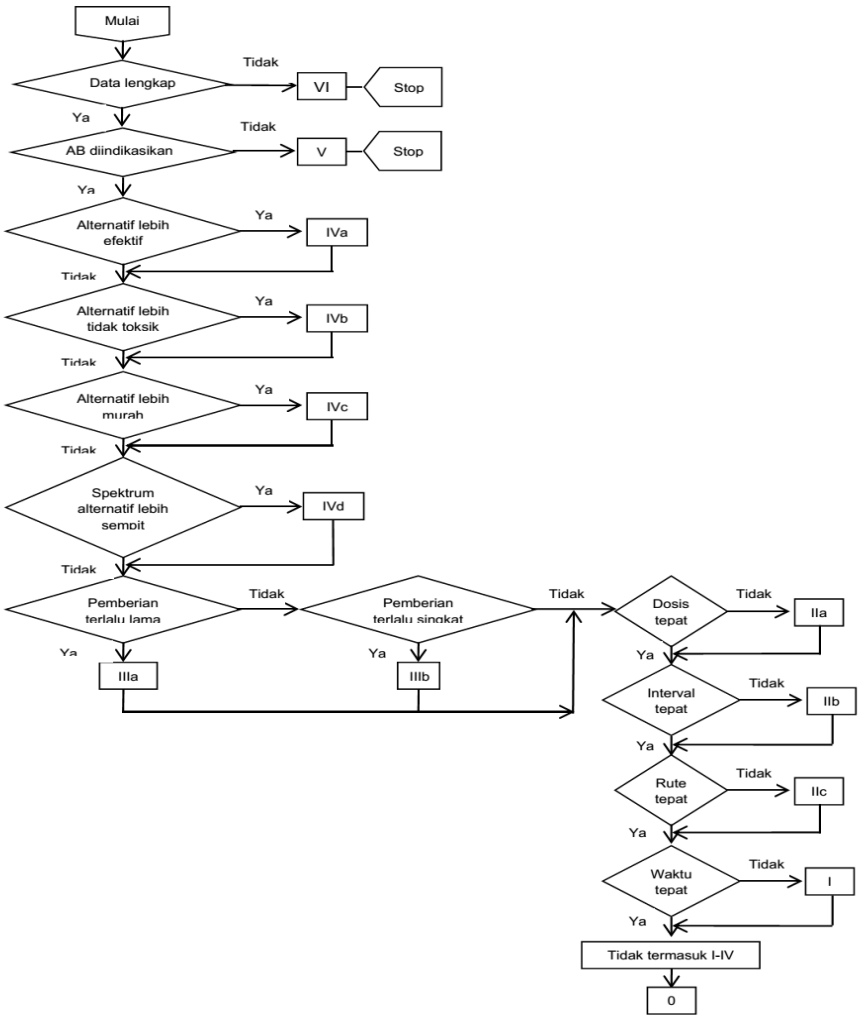

Fig. 1. Flowchart of antibiotic use quality gyssens (Limato et al., 2022)

3. RESULTS

The number of patient medical records for surgeries from September to November 2019 was 56, from which 44 medical records were randomly selected using simple random sampling, resulting in 76 antibiotic prescriptions. Based on the data regarding the distribution of antibiotic use from the 76 prescriptions for surgical patients at RSND, the most frequently prescribed antibiotics were Ceftriaxone, Cefazolin, and Cefadroxil. Additionally, based on the distribution of therapy types (Tabel 1).

In terms of therapy types for each antibiotic in surgical patients, the use of cefazolin and ceftriaxone was more commonly classified under the ADP type. Ceftriaxone was also predominantly used in the ADE type for surgical patients, while the ADU therapy type mainly used cefadroxil.

The quality of antibiotic use was assessed by reviewers based on Gyssens' criteria. The results of the quality assessment of antibiotic use in surgical patients at Diponegoro National Hospital (RSND) (Tabel 2).

The Table 2 shows that the antibiotic quality category V, which represents "no indication for antibiotic use," was most commonly administered to surgical patients.

Cost analysis was performed on antibiotics directly given to surgical patients. The total direct costs for antibiotics in each quality category for surgical patients can be seen in the Table 3.

Table 1. The distribution of therapy types

Therapy type	Case		Total prescriptions
	Surgical n = 55	Obstetric n = 21	
ADU	20 (36,4)	10 (47,6)	30 (39,5)
ADP	16 (29,1)	9 (42,9)	25 (32,9)
ADE	16 (29,1)	2 (9,5)	18 (23,7)
Aa	2 (3,6)	0 (0)	2 (2,6)
ADET	1 (1,8)	0 (0)	1 (1,3)

Note : ADU (Antimicrobial Drug Unknown Therapy). ADP (Antimicrobial Drug Prophylaxis). ADE (Antimicrobial Drug Emphiric Therapy). Aa (Alternative agent). ADET (Antimicrobial Drug Extended Empiric Therapy)

Table 2. Results of antibiotic quality assessment

Criteria for antibiotic quality	Frequency		Explanation	Percentage
	Bedah	Obgyn		
Category 0	4 (7,3)	7 (33,3)	Appropriate	11 (14,4)
Category IIA	6 (10,9)	2 (9,5)	Not Appropriate	8 (10,5)
Category IIIA	5 (9,1)	0 (0)	Not Appropriate	5 (6,6)
Category IVA	14 (25,4)	1 (4,7)	Not Appropriate	15 (19,7)
Category V	26 (47,3)	11 (52,4)	No indication	37 (48,8)

Table 3. The relationship between antibiotic quality and cost analysis

parameters	"Cost of antibiotic use" (rupiah)		Total cost (rupiah)	Gyssens criteria
	Surgical	Obstetric		
Unwise antibiotic quality (n=28)	992.604	50.028	1.003.630	Kategori I-IV
Antibiotic quality with no indication (n=37)	366.693	130.913	497.606	Kategori V
Appropriate antibiotic quality (n=11)	164.293	168.360	332.653	Kategori 0

From the Table 3, it is found that the use of inappropriate antibiotics has a higher cost value, followed by the cost of antibiotics with no indication, from the total of 76 antibiotic prescriptions.

4. DISCUSSION

In this study, the high reliance on ceftriaxone for surgical cases at RSND, accounting for 25% of prescriptions, highlights a significant trend in antibiotic use in the hospital. Ceftriaxone's exclusive use in the surgical department may indicate a lack of appropriate antibiotic selection or an over-prescription of broad-spectrum antibiotics, which could contribute to the risk of developing antibiotic resistance. The study also found that cefazolin and cefadroxil were commonly prescribed, with cefazolin being more frequently used in the OB-GYN department (38.1%) compared to the surgical department (25%). This pattern may reflect differences in the type of surgeries performed or the specific infection risks associated with each department. Cefazolin, commonly used for prophylaxis in clean surgeries, is a first-generation cephalosporin and may be more suitable for certain procedures in OB-GYN, such as cesarean sections. A critical issue highlighted in this study is the high prevalence of ADU (Antimicrobial Drug Unknown Therapy), which was the most common therapy type found. ADU refers to situations where antibiotics are prescribed without a clear or confirmed indication, which can lead to unnecessary use and contribute to antibiotic resistance (Lightner et al., 2020). The study referenced a similar issue in the study by Catharina et al., where the ADU therapy type in the surgical department before the campaign was 69.6%, and 59.1% after the campaign (Catharina et al., 2019; Tiri et al., 2020). Although there was a slight decrease in the ADU therapy rate post-campaign, the persistence of high ADU levels suggests that there is still a significant gap in appropriate antibiotic stewardship practices. This issue of

unnecessary or inappropriate antibiotic use is concerning, as it may contribute to the growing problem of antibiotic resistance. The study points to the need for more effective antibiotic stewardship programs, especially to reduce the reliance on broad-spectrum antibiotics like ceftriaxone and to ensure that antibiotics are prescribed based on clear indications rather than assumptions or routine practices. Reducing ADU and encouraging the use of more targeted antibiotics are essential steps in improving patient outcomes, minimizing unnecessary costs, and combating antibiotic resistance in the long run (Limato et al., 2022).

In the study conducted by Usman Hadid et al. in 2001-2002 at educational hospitals in Surabaya and Semarang, the results indicated notable differences in the quality of antibiotic use between the two hospitals and their respective departments. In the Surabaya hospital, 25% of antibiotics in the OB-GYN department and 22% in the surgical department fell under antibiotic quality category 0, which refers to the appropriate use of antibiotics. However, in the Semarang hospital, these figures were lower, with only 10% in the OB-GYN department and 13% in the surgical department. The study also highlighted concerns over inappropriate antibiotic use, with rates in the surgical department at 45.4% and 14.2% in the OB-GYN department. These figures were significantly higher compared to those found in Usman Hadid et al.'s previous audit in 2001-2002, where inappropriate use was reported at 13% in the surgical department and 12% in the OB-GYN department in the Surabaya hospital, and 13% and 10% respectively in the Semarang hospital (Hadi et al., 2008). The increased rates of inappropriate antibiotic use in this more recent study were attributed to several factors. One key issue identified was the excessive use of ADU (Antimicrobial Drug Unknown Therapy) antibiotics, which refers to prescribing antibiotics without clear indications or definitive microbial diagnoses (Karakoc et al., 2024). This often leads to the unnecessary switching of oral antibiotics for clean surgeries, despite no clear indication for antibiotic use. Another contributing factor was the high prescription of ADP (Antibiotic Drug Prophylaxis) antibiotics, which may be prescribed due to incorrect antibiotic selection or improper dosing practices (Tefera et al., 2020). This suggests a lack of proper diagnostic guidelines or a reliance on broad-spectrum antibiotics in routine practices, rather than targeting specific pathogens (Ahmed et al., 2024). The high rate of inappropriate antibiotic use in this study is concerning for several reasons. First, it underscores the potential for contributing to antibiotic resistance, as unnecessary antibiotic use can promote the survival of resistant strains. Furthermore, inappropriate antibiotic prescribing can lead to unnecessary healthcare costs, prolonged hospital stays, and increased morbidity and mortality. These findings emphasize the urgent need for improved antibiotic stewardship programs, especially focusing on reducing the reliance on broad-spectrum antibiotics, ensuring correct dosage, and promoting appropriate antibiotic selection based on accurate diagnoses. Proper guidelines and education for healthcare providers are necessary to reduce inappropriate antibiotic use, enhance patient safety, and ultimately combat the growing issue of antibiotic resistance (Salam et al., 2023).

The cost analysis of inappropriate antibiotic use in this study highlights the financial burden of mismanaged antibiotic prescribing in both the surgical and OB-GYN departments. In the surgical department, inappropriate antibiotic use led to a substantial cost of 992,604 IDR, while the OB-GYN department incurred 50,028 IDR, resulting in a total cost of 1,003,630 IDR. This reflects the significant financial implications of overuse or improper selection of antibiotics, which could be attributed to unnecessary prescriptions, inappropriate dosages, or incorrect antibiotic choices. In terms of antibiotics used without clear indications, the surgical department faced costs of 366,693 IDR, while the OB-GYN department incurred 130,913 IDR. These expenditures totaled 497,606 IDR. The cost of using antibiotics without indication indicates not only unnecessary drug consumption but also the potential for contributing to resistance, which could lead to further medical costs down the line. In contrast, the cost associated with appropriate antibiotic use was much lower. In the surgical department, the total cost for correct antibiotic usage was 164,293 IDR, and in the OB-GYN department, it amounted to 168,360 IDR. The combined cost for appropriate antibiotic use was 332,653 IDR, significantly lower than the costs associated with inappropriate or unnecessary use. These findings underline the financial efficiency of adhering to antibiotic stewardship principles. When antibiotics are used correctly, with appropriate indications and dosages, the costs are considerably reduced, making a strong case for the implementation of more stringent antibiotic management practices. The large

discrepancy between the costs of appropriate versus inappropriate antibiotic use in both departments also emphasizes the importance of targeted interventions, education, and guidelines to reduce unnecessary prescriptions and prevent the financial and clinical consequences of inappropriate antibiotic use, such as the development of antibiotic resistance. Additionally, the overall reduction in costs would contribute to more sustainable healthcare practices and better resource allocation within the hospital.

The discussion surrounding inappropriate antibiotic use highlights its crucial role in the rise of antibiotic resistance, which poses a serious global health threat. Inappropriate antibiotic use, whether through incorrect prescribing, overprescribing, or use without clear indications, accelerates the development of resistant pathogens. As bacteria evolve to resist the effects of antibiotics, treatments that were once effective become less so, leading to a vicious cycle of increased resistance and the need for stronger, more expensive drugs. The economic implications of antibiotic resistance are significant. As resistance increases, healthcare costs rise due to longer hospital stays, more frequent treatments, and the need for more expensive antibiotics. Patients with resistant infections may also experience higher rates of morbidity and mortality, leading to poorer health outcomes and potentially more extensive care. The report forecasting 10 million deaths linked to antibiotic resistance by 2050 underlines the urgent need for global action. If no substantial efforts are made to combat this issue, the economic losses could reach an alarming 100 million dollars (Tang et al., 2023). This highlights the broad impact that antibiotic resistance could have on global healthcare systems, economies, and public health. To mitigate these risks, it is essential to implement effective antibiotic stewardship programs, enhance public awareness about the dangers of misuse, and invest in research to develop new antibiotics and alternative treatments. The financial burden of antibiotic resistance, combined with the human toll, makes it clear that addressing this issue is not just a medical priority but also an economic necessity.

The misuse of antibiotics is a multifaceted issue, influenced by several factors that contribute to the growing problem of antibiotic resistance. One of the primary contributors is a lack of knowledge among healthcare providers. Inadequate understanding of the appropriate use of antibiotics whether due to insufficient training or a lack of awareness about resistance patterns can lead to overprescribing or incorrect prescribing practices. For example, antibiotics may be given for viral infections, where they are ineffective, or prescribed inappropriately based on an incorrect diagnosis. Another factor is patient influence. Patients often demand antibiotics for conditions like the common cold or other viral infections, despite knowing that antibiotics are ineffective against viruses. This pressure on healthcare providers, whether direct or indirect, can lead to unnecessary prescriptions. Additionally, patients may stop taking prescribed antibiotics before completing their full course, which can also contribute to the development of resistance (Salam et al., 2023).

The pharmaceutical industry plays a significant role in antibiotic misuse as well. Through aggressive marketing and promotion, pharmaceutical companies can influence prescribing behavior, encouraging the use of certain antibiotics, even when alternatives might be more appropriate. Furthermore, the availability of antibiotics without prescription in some regions exacerbates the problem by enabling self-medication. Hospital local policies and guidelines also contribute to this issue. If a hospital lacks clear and effective antimicrobial stewardship programs or guidelines, antibiotic misuse may occur more frequently. In some cases, institutional protocols may inadvertently encourage the use of broad-spectrum antibiotics or delay switching to more targeted treatments. Hospital administration and healthcare policymakers can sometimes fail to implement or enforce practices that encourage the responsible use of antibiotics. Given these complexities, it is clear that antibiotic misuse requires a comprehensive approach. Antibiotic Stewardship Guidelines—tailored to the specific microbial landscape and resistance patterns of a given hospital or region—are crucial in promoting appropriate antibiotic use. These guidelines can help healthcare providers make informed decisions based on the most current evidence and data, ultimately reducing unnecessary antibiotic use, minimizing the development of resistance, and improving patient outcomes (Pollack & Srinivasan, 2014).

Additionally, antibiotic stewardship programs should incorporate continuous education for healthcare providers, patient education on the importance of not demanding or misusing antibiotics, and robust monitoring of antibiotic

use and resistance patterns. Collaborative efforts between doctors, patients, the pharmaceutical industry, and policymakers are essential to curb the growing threat of antibiotic resistance and ensure that antibiotics remain effective for future generations (UK GOV, 2024).

5. LIMITATIONS OF THE STUDY

This study has several limitations that should be acknowledged. First, the sample size used is relatively small, with only 43 medical records in the pre-campaign phase and 43 in the post-campaign phase, which may limit the generalizability of the findings. Second, data collection relied on medical records, which can introduce bias due to the completeness and accuracy of the recorded information, such as potential errors in documenting the type of antibiotics prescribed. Additionally, the study did not account for external factors, such as hospital policies or staff training, which could influence antibiotic prescribing decisions. Therefore, further research with a larger and more in-depth design is needed to address these limitations.

6. CONCLUSION

The conclusion of this study highlights a critical issue in healthcare: the high costs associated with the inappropriate and unnecessary use of antibiotics, particularly when antibiotics are prescribed without a valid medical indication or when the wrong antibiotics are chosen. This leads to a waste of healthcare resources and exacerbates the growing problem of antibiotic resistance, which can have long-term negative effects on patient health and healthcare systems.

The importance of more effective antibiotic management strategies is emphasized, including the implementation of antibiotic stewardship programs in hospitals designed to optimize antibiotic use. These programs ensure that antibiotics are prescribed only when necessary, in the correct dosage, and for the appropriate duration. By reducing unnecessary antibiotic prescriptions, hospitals can significantly reduce healthcare costs while also decreasing the risk of antibiotic resistance.

Additionally, the study underscores the importance of educating healthcare providers on the proper use of antibiotics, as well as educating patients about the dangers of antibiotic misuse. Effective management involves collaboration between healthcare professionals, policymakers, and patients to promote responsible antibiotic use and ensure that antibiotics remain an effective tool for treating infections.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The authors hereby state that NO generative AI tools such as large language models (ChatGPT, COPILOT, etc.) or text-to-image generators were utilized in the creation or editing of this work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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