



Analysis of the status of antibiotic consumption in inpatient treatment using the WHO AWaRe classification system at Hospital 199 - Ministry of Public Security (2022 - 2024)

Phân tích thực trạng tiêu thụ thuốc kháng sinh trong điều trị nội trú bằng hệ thống phân loại AWaRe – WHO tại Bệnh viện 199 (Bộ Công an) giai đoạn 2022 - 2024

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Abstract

Objectives: Analysis of the inpatient antibiotic consumption status using the WHO AWaRe classification system at Hospital 199 – Ministry of Public Security during the period 2022 – 2024.

Subjects and methods: The cross-sectional descriptive study based on retrospective data on the antibiotic use list of inpatients throughout Hospital 199 and several clinical departments from January 1, 2022 to December 31, 2024.

Results: The overall antibiotic consumption rate at the hospital was 102.19 DDD per 100 bed-days, increasing sharply from 60.78 DDD/100 bed-days in 2022 to 127.11 in 2023, before slightly decreasing to 115.08 in 2024. The β -lactam class overwhelmingly dominated usage - accounting for 62.65 DDD/100 bed-days (equivalent to 61.30%). Within this class, penicillins combined with β -lactamase inhibitors were most consumed, reaching 24.19 DDD/100 bed-days (38.62%), followed by C3G with 19.20 DDD/100 bed-days (30.65%). According to the WHO AWaRe classification, Access group antibiotics accounted for 40.63% (41.52 DDD/100 bed-days), while the Watch group represented 59.32% (60.62 DDD/100 bed-days). The Reserve group made up only 0.05% (0.05 DDD/100 bed-days). Specifically, colistin increased from 0.0002% to 0.003%, linezolid from 0% to 0.08%, and fosfomycin from 0.0001% to 0.04% over the study period.

Conclusion: The above results are a basis for evaluating the situation of antibiotic use and improving treatment quality.

Keywords: antibiotic consumption; antibiotic resistance; defined daily dose; DDD per 100 bed-days; AwaRe; Hospital 199.

Tóm tắt

Mục tiêu: Phân tích thực trạng tiêu thụ thuốc kháng sinh trong điều trị nội trú bằng hệ thống phân loại AWaRe – WHO tại Bệnh viện 199 (Bộ Công an) giai đoạn 2022 – 2024.

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Đối tượng và phương pháp: Nghiên cứu mô tả cắt ngang dựa trên cơ sở hồi cứu số liệu danh mục sử dụng thuốc kháng sinh của các bệnh nhân điều trị nội trú trên toàn Bệnh viện 199 sáng từ ngày 01/01/2022 đến ngày 31/12/2024.

Kết quả: Mức độ tiêu thụ kháng sinh của Bệnh viện là 102,19 DDD/100 ngày điều trị. Từ 60,78 DDD/100 ngày giường năm 2022, tăng mạnh lên 127,11 DDD/100 ngày giường năm 2023, giảm còn 115,08 DDD/ 100 ngày giường năm 2024. Nhóm β -lactam chiếm ưu thế vượt trội - đạt 62,65 DDD/100 ngày giường (chiếm 61,30%). Trong đó, nhóm Penicillin + ức chế men β -lactamase đạt 24,19 DDD/100 ngày giường (38,62%). C3G đứng thứ hai với mức tiêu thụ 19,20 DDD/100 ngày giường (30,65%). Nhóm Access chiếm 40,63% (41,52 DDD/100 ngày giường), Watch chiếm 59,32% (60,62 DDD/100 ngày giường). Nhóm Reserve chiếm 0,05% (0,05 DDD/100 ngày giường). Cụ thể, colistin tăng từ 0,0002% lên 0,003%, linezolid từ 0% lên 0,08%, và fosfomycin từ 0,0001% lên 0,04%.

Kết luận: Kết quả trên là cơ sở giúp đánh giá tình hình sử dụng thuốc kháng sinh, nâng cao chất lượng điều trị.

Từ khóa: tiêu thụ kháng sinh; đề kháng kháng sinh; phân tích liều xác định trong ngày; DDD/ 100 ngày giường; AwaRe; Bệnh viện 199.

1. Introduction

Since the discovery of penicillin in 1928, antibiotics have transformed medicine, saving millions of lives worldwide [6]. Yet, their effectiveness is increasingly threatened by antimicrobial resistance (AMR), now recognized as one of the greatest global health challenges. In 2019, AMR directly caused 1.27 million deaths and contributed to nearly 5 million, with projected economic losses reaching USD 100 trillion [8].

At the national level, Viet Nam faces an even more alarming situation. Easy access to antibiotics without prescription, self-medication, and empirical prescribing without microbiological testing have accelerated resistance. Treating resistant infections costs two to three times more than susceptible cases, creating an annual economic burden of USD 1–2 billion, equivalent to 1–2% of the national health budget [7].

In this context, the World Health Organization (WHO) launched the AWaRe classification in 2017, updated in 2021. AWaRe categorizes antibiotics into three groups: Access (narrow-spectrum, lower resistance potential), Watch (broad-spectrum, requiring monitoring), and Reserve (last-resort for multidrug-resistant infections). WHO emphasizes prioritizing Access antibiotics as a global policy goal, consistent with Viet Nam's National Action Plan on AMR for 2023–2030 [18, 20].

Evaluating antibiotic consumption patterns at the hospital level is essential to identify gaps and guide stewardship interventions. Hospital 199, a Grade I general hospital serving police officers and the local population in the central highlands, provides a suitable setting for such evaluation. As a pioneer in digital health and antibiotic stewardship, the hospital has implemented systems to monitor and optimize antibiotic use [12].

Therefore, this study, titled: “Analysis of the consumption status of antibiotics in inpatient treatment using the WHO AWaRe classification system at Hospital 199 - Ministry of Public Security (2022 – 2024)”, aims to:

- *Analyze the status of inpatient antibiotic consumption at Hospital 199 during 2022–2024 based on Defined Daily Doses (DDD) per 100 bed-days.*

- *Analyze inpatient antibiotic consumption at Hospital 199 during 2022–2024 according to the WHO AWaRe classification system.*

2. Subjects and methods

2.1. Study subjects

The study included the list of antibiotics used, their consumption volume, and the number of inpatient bed-days recorded from January 1, 2022, to December 31, 2024, as stored in the hospital management software at Hospital 199.

2.1.1. Inclusion criteria

- Antibiotics prescribed to patients aged 18 years and above.

- Clinical departments with inpatient treatment.

2.1.2. Exclusion criteria

- Antibiotics without WHO-defined DDD values.

2.2. Research methods

2.2.1. Study design

This study employed a retrospective descriptive design, analyzing data from Hospital 199 during the period 2022–2024. A retrospective approach was adopted to quantitatively assess the extent of antibiotic use through the indicator of Defined Daily Doses (DDD) per 100 bed-days.

$$\text{DDD/100 bed-days} = \frac{\text{DDD} \times \text{Number of bed-days}}{\text{Total grams used} \times 100}$$

2.2.2. Data collection

Data were obtained from hospital records, including the list of antibiotics used and reports on inpatient pharmaceutical stock management (procurement, distribution, and inventory) at Hospital 199 during 2022–2024. All data were extracted from the hospital management software.

2.2.3. Data analysis and processing

The collected data were cleaned, entered, coded, and analyzed using Microsoft Excel 2019 and SPSS version 20 software.

2.3. Research indicators

According to the WHO AWaRe 2023 classification, a total of 257 antibiotics are categorized into three groups: Access, Watch, and Reserve. At Hospital 199 during 2022–2024, 16 of 87 Access group antibiotics, 27 of 141 Watch group antibiotics, and 3 of 29 Reserve group antibiotics were utilized. The WHO recommends that Access group antibiotics should account for at least 60% of the hospital’s total antibiotic consumption [19].

3. Results

3.1. Analysis of inpatient antibiotic consumption based on DDD per 100 bed-days at 199 Hospital during 2022–2024.

3.1.1. Overall antibiotic consumption (DDD/100 bed-days) at hospital level.

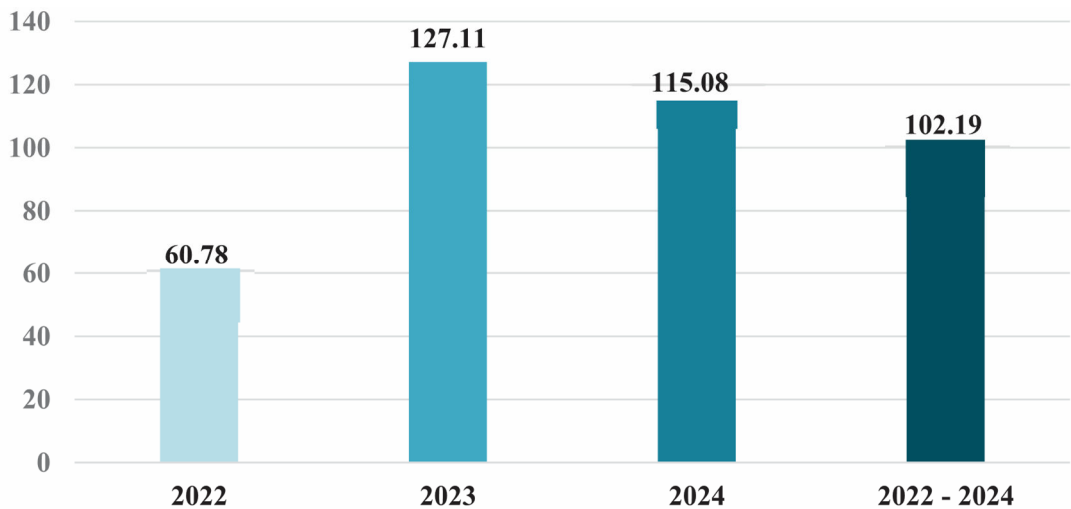


Figure 1. Antibiotic consumption in inpatient treatment, expressed as DDD/100 bed-days.

Observation: The average inpatient antibiotic consumption at Hospital 199 during 2022–2024 was 102.19 DDD/100 bed-days. Yearly trends showed a sharp increase from 60.78 DDD/100

bed-days in 2022 to 127.11 in 2023 (a 109% increase), followed by a slight decline to 115.08 in 2024 (a 9.5% decrease).

3.1.2. Antibiotic consumption by chemical class at hospital level

Table 1. Inpatient antibiotic consumption by chemical class (DDD/100 bed-days) at Hospital 199, 2022–2024

No.	Antibiotic class	DDD/100 bed-days							
		2022	%	2023	%	2024	%	2022 – 2024	%
1	β-lactams	36.10	59.39	72.55	57.08	78.36	68.03	62.65	61.30
2	Quinolones	10.50	17.28	21.34	16.79	13.34	11.60	15.47	15.14
3	Macrolides	7.00	11.52	17.10	13.45	17.01	14.78	13.89	13.59
4	Tetracyclines	3.17	5.21	8.82	6.94	1.13	0.98	4.77	4.67
5	Nitroimidazoles	2.41	3.96	4.42	3.48	3.36	2.92	3.32	3.25
6	Aminoglycosides	1.15	1.89	2.27	1.79	1.21	1.05	1.54	1.51
7	Glycopeptides	0.30	0.49	0.12	0.09	0.39	0.39	0.25	0.24
8	Lincosamides	0.12	0.20	0.36	0.28	0.10	0.09	0.19	0.19
9	Others	0.03	0.06	0.13	0.10	0.18	0.16	0.11	0.11
Total		60.78	100	127.11	100	115.08	100	102.19	100

Observation: As shown in Table 1, β-lactams dominated overall antibiotic consumption, averaging 62.65 DDD/100 bed-days (61.30%), more than doubling from 36.10 DDD/100 bed-days (59.39%) in 2022 to 78.36 (68.03%) in 2024. Quinolones ranked second with an average of 15.47 DDD/100 bed-days (15.14%), increasing from 10.50 (17.28%) in 2022 to 21.34 (16.79%) in 2023, before declining to 13.34 (11.60%) in 2024.

3.1.3. Consumption of β-lactam antibiotics at hospital level

Table 2. Inpatient consumption of β-lactam antibiotics (DDD/100 bed-days) at Hospital 199, 2022–2024

No.	β-lactam subgroup	DDD/100 bed-days							
		2022	%	2023	%	2024	%	2022 - 2024	%
1	Penicillins	3.24	8.98	8.65	11.93	4.18	5.33	5.51	8.79
2	Penicillins + β-lactamase inhibitors	10.46	28.98	28.50	39.28	33.44	42.70	24.19	38.62
3	C1G	1.62	4.50	2.55	3.51	2.76	3.52	2.33	3.72
4	C2G	5.46	15.12	7.25	9.99	15.38	19.60	9.23	14.73
5	C3G	14.49	40.15	22.44	30.93	20.57	26.25	19.20	30.65
6	C4G	0.04	0.11	0.98	1.35	0.77	0.98	0.61	0.97
7	Carbapenems	0.78	2.16	2.18	3.01	1.27	1.62	1.58	2.52
Total		36.10	100	72.55	100	78.36	100	62.65	100

Observation: As shown in Table 2, during 2022–2024, the Penicillins + β-lactamase inhibitors subgroup ranked first, with an average of 24.19 DDD/100 bed-days (38.62%), rising more than threefold from 10.46 (28.98%) in 2022 to 33.44 (42.70%) in 2024. The third-generation cephalosporins (C3G) ranked second, averaging 19.20 DDD/100 bed-days (30.65%), increasing from 14.49 (40.15%) in 2022 to 20.57 (26.25%) in 2024, despite a slight decline compared to 22.44 (30.93%) in 2023.

3.2. Analysis of inpatient antibiotic consumption using the WHO AWaRe classification system at 199 during 2022–2024.

3.2.1. Antibiotic consumption by AWaRe classification – hospital – wide.

Table 3. Inpatient antibiotic consumption by AWaRe classification (DDD/100 bed-days) at Hospital 199.

No.	AWaRe group	DDD/100 bed-days							
		2022	%	2023	%	2024	%	2022 – 2024	%
1	Access	22.03	36.24	55.42	43.60	45.49	39.53	41.52	40.63
2	Watch	38.75	63.76	71.68	56.39	69.45	60.35	60.62	59.32
3	Reserve	0.0002	0.0003	0.012	0.01	0.14	0.12	0.05	0.05
Total		60.78	100	127.11	100	115.08	100	102.19	100

Observation: The Watch group accounted for the highest share at 59.32% (60.62 DDD/100 bed-days), far exceeding the access group at 40.63% (41.52 DDD/100 bed-days). The Reserve group was extremely low at 0.05% (0.05 DDD/100 bed-days). The Watch group declined from 63.76% (38.75 DDD/100 bed-days) in 2022 to 56.39% (71.68 DDD/100 bed-

days) in 2023, before rebounding to 60.35% (69.45 DDD/100 bed-days) in 2024. The Reserve group showed a progressive increase: from 0.0003% (0.0002 DDD/100 bed-days) in 2022 to 0.01% (0.012 DDD/100 bed-days) in 2023, and sharply up to 0.12% (0.14 DDD/100 bed-days) in 2024.

3.2.2. Antibiotic consumption by chemical class within AWaRe classification – hospital – wide

Table 4. Proportion of inpatient antibiotic consumption by chemical class and AWaRe classification at Hospital 199.

Antibiotic class	Consumption proportion (%)								
	2022			2023			2024		
	Access	Watch	Reserve	Access	Watch	Reserve	Access	Watch	Reserve
β-lactams	25.07	34.32	0	31.10	25.98	0	35.50	32.53	0
Quinolones	0	17.28	0	0	16.79	0	0	11.60	0
Macrolides	0	11.52	0	0	13.45	0	0	14.78	0
Tetracyclines	5.21	0	0	6.94	0	0	0.98	0	0
Nitroimidazoles	3.96	0	0	3.48	0	0	2.92	0	0
Aminoglycosides	1.76	0.13	0	1.74	0.05	0	0.04	1.01	0
Glycopeptides	0	0.49	0	0	0.09	0	0	0.39	0
Lincosamides	0.20	0	0	0.28	0	0	0.09	0	0
Sulfonamides	0.04	0	0	0.06	0	0	0	0	0
Rifamycins	0	0.02	0	0	0.03	0	0	0.04	0
Polymyxins	0	0	0.0002	0	0	0.001	0	0	0.003
Phosphonic acids	0	0	0.0001	0	0	0.007	0	0	0.04
Oxazolidinones	0	0	0	0	0	0.002	0	0	0.08
Total	36.24	63.76	0.0003	43.60	56.39	0.01	39.53	60.35	0.12

Observation: The β -lactam (access group) increased steadily from 25.07% (2022) to 31.10% (2023) and 35.50% (2024), forming the majority within the Access category. The quinolone (watch group) showed a positive downward trend, from 17.28% (2022) to 11.60% (2024). Notably, within the reserve group, consumption of polymyxins (colistin) rose from 0.0002% to 0.003%, oxazolidinones (linezolid) from 0% to 0.08%, and phosphonic acids (fosfomycin) from 0.0001% to 0.04% over the study period.

4. Discussion

4.1. Analysis of antibiotic consumption in inpatient treatment based on DDD/100 bed-days at Hospital 199 during 2022–2024.

4.1.1. Antibiotic consumption (DDD/100 bed-days) across the hospital.

The average antibiotic consumption at Hospital 199 during 2022–2024 was 102.19 DDD/100 bed-days. However, compared with some provincial hospitals such as Kien An Hospital in 2020 (64.60 DDD/100 bed-days) and Thuy Nguyen Hospital during 2021–2023 (52.83 DDD/100 bed-days) [11, 16], the consumption at Hospital 199 remained higher. This difference can be attributed to the burden of severe infections at Hospital 199, where infection prevalence reached 88.2% (Dec 2022–Aug 2023), including 88.1% antibiotic-resistant bacteria and 84.7% multidrug-resistant organisms [14].

At the international level, the consumption at Hospital 199 fell within the range of 50–120 DDD/100 bed-days, similar to that of middle-income countries [4], but far higher than regions with advanced antimicrobial stewardship systems, such as EU/EEA in 2022 (47.7 DDD/100 bed-days), where microbiological testing and antimicrobial management programs (e.g., ESAC-Net) are highly effective [2].

By year, antibiotic use at Hospital 199 varied significantly: from 60.78 DDD/100 bed-days in 2022, increasing sharply to 127.11 in 2023 (+109%), before slightly decreasing to 115.08 in 2024 (–9.5%). The low figure in 2022 was due to strict COVID-19 prevention measures early in the year, including social distancing, which reduced inpatient cases and common infections. In 2023, demand for medical services surged following the pandemic, alongside a rise in complicated infections such as ventilator-associated pneumonia and sepsis [10]. Additionally, the expansion of hospital capacity and admission of over 10,000 international patients during 2023–2024 also contributed to increased antibiotic consumption [12].

Importantly, the establishment of the antibiotic management board at Hospital 199, in accordance with Decision 5631/QĐ-BYT (December 31, 2020) and guided by the Handbook issued under Decision 2115/QĐ-BYT (May 11, 2023), also played a critical role. This board contributed to strengthening antibiotic stewardship, approving prescriptions for restricted antibiotics, monitoring antimicrobial resistance trends, and supporting clinicians in rational antibiotic use [12].

4.1.2. Antibiotic consumption by chemical class across the hospital.

During 2022–2024, β -lactams predominated at Hospital 199, averaging 62.65 DDD/100 bed-days (61.30%). This trend was consistent with other Vietnamese hospitals such as Kien An Hospital in 2020 (72.60%) and Thuy Nguyen General Hospital in 2023 (75.73%) [11, 16]. A study of 303 hospitals across 53 countries also reported that hospitals in Northern and Western Europe prioritized β -lactams due to efficacy and cost-effectiveness [17]. In contrast, in the Netherlands, β -lactams accounted for only 40–45% of antibiotic use due to strategies prioritizing narrow-spectrum agents [13]. At

Hospital 199, β -lactam use more than doubled, from 36.10 DDD/100 bed-days (59.39%) in 2022 to 78.36 (68.03%) in 2024. This reflects treatment pressures from multidrug-resistant gram-negative bacteria such as *Acinetobacter spp.* (83.33%) and *Pseudomonas spp.* (66.28%) [22]. Notably, *Pseudomonas spp.* showed 100% resistance to ampicillin and ticarcillin, 50% resistance to cefotaxime, but 80% susceptibility to imipenem, indicating the need to prioritize potent β -lactams such as carbapenems in treatment [14].

Quinolones ranked second with an average of 15.47 DDD/100 bed-days (15.14%), rising from 10.50 in 2022 (17.28%) to 21.34 in 2023 (16.79%), before declining to 13.34 in 2024 (11.60%). This pattern, with quinolones second only to β -lactams, was also observed in other major Vietnamese hospitals such as Kien An Hospital (12.23%) and Thuy Nguyen Hospital (13.39%) [11, 16]. *Pseudomonas spp.* was 100% susceptible to ofloxacin, explaining the sustained use of quinolones, whereas *Streptococcus spp.* showed high resistance to ofloxacin (55%) and norfloxacin (75%), raising concerns over quinolone resistance [14].

Macrolides ranked third, averaging 13.89 DDD/100 bed-days (13.59%), with a steady increase from 7.00 in 2022 (11.52%) to 17.01 in 2024 (14.78%). Macrolides were often used in respiratory infections, where *Streptococcus spp.* (76.77% multidrug-resistant) was a common pathogen at Hospital 199 [14]. Particularly after the COVID-19 pandemic, the increase in community-acquired pneumonia cases complicated treatment, often requiring combination with β -lactams or vancomycin in severe resistance cases [10]. However, the continuous rise in macrolide use warrants close monitoring, as *Streptococcus spp.* exhibited 50% resistance to erythromycin, and

Streptococcus pneumoniae resistance rates reached 96–97% in Vietnam [9].

Aminoglycosides remained below 2%, reflecting cautious use due to nephrotoxicity and ototoxicity risks [1], though still employed because *Pseudomonas spp.* was 92.6% susceptible to amikacin [14].

4.1.3. Consumption of β -lactam antibiotics across the hospital.

The β -lactam consumption structure at Hospital 199 during 2022–2024 revealed a strong reliance on penicillin + β -lactamase inhibitors and third-generation cephalosporins (C3G), which together accounted for nearly 70% of total β -lactam use. Penicillin + β -lactamase inhibitors led, averaging 24.19 DDD/100 bed-days (38.62%), more than tripling from 10.46 (28.98%) in 2022 to 33.44 (42.70%) in 2024. This trend reflects increasing demand for combination antibiotics in managing complex infections caused by gram-negative β -lactamase-producing bacteria. Notably, *Pseudomonas spp.* was 66.5% resistant to amoxicillin/clavulanic acid, raising the risk of treatment failure and further pressure on this group [14].

C3G ranked second, averaging 19.20 DDD/100 bed-days (30.65%), rising from 14.49 in 2022 (40.15%) to 20.57 in 2024 (26.25%), despite a slight decline from 22.4 (30.93%) in 2023. C3G played a key role in treating gram-negative infections – the main pathogens in nosocomial infections – consistent with global practice where ceftriaxone (a representative C3G) remains a first-line agent in Asia and Latin America [17]. However, careful monitoring of C3G use is required to prevent resistance, particularly as *Pseudomonas spp.* (66.28% multidrug-resistant) showed 50% resistance to cefotaxime and *Streptococcus spp.* (76.77% multidrug-resistant) was completely resistant to

ceftriaxone at 199 Hospital, amid rising cephalosporin resistance in Vietnam [10, 14].

Second-generation cephalosporins (C2G) ranked third, averaging 9.23 DDD/100 bed-days (14.73%), nearly tripling from 5.46 (15.12%) in 2022 to 15.38 (19.60%) in 2024. This suggests that Hospital 199 increasingly favored moderate-spectrum antibiotics for mild to moderate infections or surgical prophylaxis, thereby reducing selective pressure compared to C3G. C2G was effective against *Pseudomonas spp.* (80% susceptible to cefuroxime), but ineffective against *Streptococcus spp.* (100% resistant), explaining its selective use for mild gram-negative infections [14]. In contrast, plain penicillin declined from 3.24 (8.98%) in 2022 to 2.41 (3.07%) in 2024, due to limited efficacy against β -lactamase-producing bacteria, particularly as *Pseudomonas spp.* and *Streptococcus spp.* showed 66.5% and 100% resistance to penicillin, respectively [14].

Carbapenems, the broadest-spectrum β -lactams, accounted for only 2.52% (mean 1.58 DDD/100 bed-days), decreasing from 2.18 (3.01%) in 2023 to 1.27 (1.62%) in 2024. This low and declining trend reflects strict control at Hospital 199, reserving carbapenems for multidrug-resistant infections such as MRSA and *Staphylococcus spp.* (85.71% multidrug-resistant), in line with Decision 5631/QĐ-BYT [6]. This represents a positive signal toward mitigating carbapenem resistance – a critical challenge in Vietnam [15].

4.2. Analysis of inpatient antibiotic consumption using the WHO AWaRe classification at Hospital 199 during 2022–2024.

4.2.1. Antibiotic consumption by AWaRe – WHO classification across the hospital

From 2022 to 2024, the antibiotic consumption structure at Hospital 199 demonstrated a pronounced imbalance

according to the WHO AWaRe classification. The Watch group accounted for the highest proportion at 59.32% (60.62 DDD/100 bed-days), far exceeding the Access group at 40.63% (41.52 DDD/100 bed-days), while the Reserve group was extremely low at 0.05% (0.05 DDD/100 bed-days). The proportion of access antibiotics fell well below the WHO-recommended minimum threshold of 60% [18, 19]. This pattern reflects suboptimal antibiotic use, raising the risk of escalating multidrug resistance (MDR), increased treatment costs, and compromised effectiveness of strategic antibiotics at the hospital.

The Watch group showed fluctuating consumption trends, decreasing from 63.76% (38.75 DDD/100 bed-days) in 2022 to 56.39% (71.68 DDD/100 bed-days) in 2023, before rising again to 60.35% (69.45 DDD/100 bed-days) in 2024. Overreliance on this group, particularly when overall antibiotic use peaked at 127.11 DDD/100 bed-days in 2023, reflects mounting treatment pressure against increasingly complex resistant pathogens, with 88.1% resistant strains and 84.7% multidrug-resistant strains reported at Hospital 199 [14]. Internationally, this rate far exceeded that of developed countries such as the Netherlands in 2023 (31.2%) and Iceland in 2022 (13.58%), where robust antimicrobial stewardship programs were implemented through significant investment in microbiological testing and strict control policies [2, 13]. These disparities highlight the urgent need for Hospital 199 to establish a long-term strategy to reduce reliance on the Watch group.

Conversely, the access group displayed inconsistency in prioritizing safer antibiotics, rising from 36.24% (22.03 DDD/100 bed-days) in 2022 to 43.60% (55.42 DDD/100 bed-days) in 2023, but declining again to 39.53% (45.49 DDD/100 bed-days) in 2024. The increase in

2023 was a positive signal, reflecting efforts to employ narrow-spectrum antibiotics for common infections. However, the subsequent decline in 2024 demonstrated limited sustainability, as severe cases necessitated shifting to the Watch group. Compared with developed countries such as the Netherlands in 2023 (67.5%) and Iceland in 2022 (65.2%) [2, 13], the gap remains substantial, as these countries successfully implemented access-first strategies through stringent antibiotic stewardship policies and extensive physician training. Other factors also contribute to inter-hospital variations, including local resistance patterns, treatment characteristics of each unit, antibiotic availability, and national health insurance reimbursement regulations.

The Reserve group showed a significant increase, from 0.0003% (0.0002 DDD/100 bed-days) in 2022 to 0.009% (0.012 DDD/100 bed-days) in 2023, and sharply rising to 0.12% (0.14 DDD/100 bed-days) in 2024 - nearly a 12-fold increase. This surge in 2024 reflected growing pressure from severe MDR infections, particularly *Acinetobacter spp.* (83.33%), *Staphylococcus spp.* (85.71%), and *E. coli* (71.43%), compelling the hospital to resort to last-line antibiotics [18, 22]. Nevertheless, with an overall average of only 0.05%, the Reserve group remained within WHO recommendations to restrict strategic antibiotic use, thereby limiting the emergence of superbugs and preserving long-term treatment efficacy [18, 19]. However, the steep rise in 2024 is alarming, underscoring the need for Hospital 199 to strengthen surveillance of resistant bacteria, optimize treatment regimens, and enhance infection prevention measures to avoid overuse of reserve antibiotics. In line with Decision 5631/QĐ-BYT (December 31, 2020) and Decision 2115/QĐ-BYT (May 11, 2023), the hospital should establish and enforce a formal procedure for approving the use of reserve

antibiotics under the supervision of the antibiotic management board. Regular antibiotic stewardship program implementation, physician training, and prescription audits will be essential to ensure reserve antibiotics are strictly controlled and only used when absolutely necessary.

4.2.2. Antibiotic consumption by chemical structure within the AWaRe – WHO framework across the hospital.

Between 2022 and 2024, the antibiotic consumption structure at Hospital 199, classified by chemical group and AWaRe system, revealed an alarming imbalance, with β -lactams dominating both the Access and Watch categories. Access β -lactams steadily increased from 25.07% (2022) to 31.10% (2023) and 35.50% (2024), representing the majority of access consumption. This was a positive signal, reflecting prioritization of narrow-spectrum antibiotics such as amoxicillin/ clavulanic acid, consistent with WHO recommendations [18]. However, resistance remained a challenge, with *Pseudomonas spp.* (66.28% MDR) resistant to 66.5% of amoxicillin/clavulanic acid and 100% to ampicillin, while *Streptococcus spp.* (76.77% MDR) showed 100% resistance to ampicillin at 199 Hospital [14]. Watch β -lactams fluctuated, decreasing from 34.32% (2022) to 25.98% (2023), before rising again to 32.53% (2024). The 2024 increase, mainly driven by third-generation cephalosporins (C3G) such as cefotaxime and ceftriaxone, poses a potential risk of promoting MDR pathogens, as *Pseudomonas spp.* exhibited 50% resistance to cefotaxime.

Quinolones (watch) showed a favorable downward trend, from 17.28% (2022) to 11.60% (2024), aligning with EMA warnings regarding severe adverse effects (neuropathy, tendon damage) and cross-resistance [3]. Nonetheless, resistance concerns persisted, with

Streptococcus spp. resistant to 75% of norfloxacin, although *Pseudomonas spp.* remained 100% sensitive to ofloxacin [14].

Aminoglycosides showed redistribution between AWARe groups: access decreased markedly from 1.76% (2022) to 0.04% (2024), while watch (mainly amikacin) increased from 0.13% (2022) to 1.01% (2024). This rise was linked to severe infections by *Pseudomonas spp.* and *Acinetobacter spp.*, which were 92.6% sensitive to amikacin [14, 22]. However, amikacin carries risks of nephrotoxicity and ototoxicity, requiring close clinical monitoring [5]. Similarly, glycopeptides (watch), mainly vancomycin, increased slightly from 0.20% (2022) to 0.39% (2024), supported by sensitivity rates of 90.9% in *Streptococcus spp.* and 100% in *Pseudomonas spp.* [14].

Notably, the Reserve group, including polymyxins (colistin), oxazolidinones (linezolid), and phosphonics (fosfomycin), showed a concerning upward trend: colistin increased from 0.0002% to 0.003%, linezolid from 0% to 0.08%, and fosfomycin from 0.0001% to 0.04%. This reflects treatment pressure from severe MDR infections, particularly caused by *Acinetobacter spp.* and *Pseudomonas spp.*, the latter being 91.3% sensitive to colistin [14]. *Pseudomonas spp.* is recognized by WHO as a “priority pathogen” due to its high resistance potential and risk of global spread. Thus, strict control of Reserve antibiotic use is essential to prevent inappropriate therapy and further resistance development [18]. Colistin, in particular, is associated with severe nephrotoxicity and neurotoxicity [21]. Therefore, Hospital 199 should strengthen resistant bacteria surveillance and leverage AI/digital health technologies, while integrating specific stewardship measures mandated by the Ministry of Health, including prior-authorization policies, prescription audits,

and periodic evaluation by the antibiotic management board.

5. Conclusion

Analysis of inpatient antibiotic consumption at Hospital 199 (2022–2024), based on the WHO AWARe classification, yielded the following findings:

- By DDD per 100 bed-days

The overall antibiotic consumption reached 102.19 DDD/100 bed-days. It increased markedly from 60.78 DDD/100 bed-days in 2022 to 127.11 in 2023 (a 109% increase), followed by a slight decrease to 115.08 in 2024 (a 9.5% reduction).

β -lactams were the predominant class, accounting for 62.65 DDD/100 bed-days (61.30%), more than doubling from 36.10 DDD/100 bed-days (59.39%) in 2022 to 78.36 DDD/100 bed-days (68.03%) in 2024. Quinolones ranked second, with 15.47 DDD/100 bed-days (15.14%).

Within the β -lactam group, penicillins combined with β -lactamase inhibitors had the highest consumption at 24.19 DDD/100 bed-days (38.62%), followed by C3G at 19.20 DDD/100 bed-days (30.65%).

- By WHO AWARe classification

The Access group accounted for 40.63% (41.52 DDD/100 bed-days), the Watch group for 59.32% (60.62 DDD/100 bed-days), and the Reserve group for 0.05% (0.05 DDD/100 bed-days).

Among β -lactams classified as access, the proportion showed a steady increase, from 25.07% in 2022 to 31.10% in 2023, reaching 35.50% in 2024. In contrast, quinolones (Watch group) declined from 17.28% in 2022 to 11.60% in 2024.

Reserve antibiotics showed a concerning upward trend: colistin increased from 0.0002%

to 0.003%, linezolid from 0% to 0.08%, and fosfomycin from 0.0001% to 0.04%.

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