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Evaluating Antimicrobial Stewardship Deficits and WHO AWaRe Alignment in Conflict-Affected Tertiary Hospitals: A Quantitative Study from Sana'a, Yemen

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Abstract

Background

The rapid rise of antimicrobial resistance is a critical global public health crisis, presenting severe challenges in fragile, conflict-affected healthcare systems. While antimicrobial stewardship programs optimize antibiotic use, the capacity for implementing these initiatives in Yemen remains deeply under-researched. This study evaluated inpatient antibiotic prescribing patterns, WHO Access, Watch, and Reserve (AWaRe) alignment, and chart documentation completeness across public and private tertiary hospitals in Sana'a, Yemen.

Methods

Across-sectional medical record audit was conducted across acute clinical departments Intensive Care Unit, Surgery, and Internal Medicine in one public (Hospital 1) and one private (Hospital 2) tertiary hospitals in Sana'a over a 12-month period (March 2025-March 2026). Systematic random sampling yielded 379 inpatient records evaluating 775 individual antibiotic prescriptions. Prescribed antibiotics were evaluated using the WHO AWaRe classification, diagnostic stewardship indicators, and documentation completeness.

Results

Prescribing was heavily dominated by Watch-group antibiotics (67.1%, n = 520/775), followed by Access (26.6%, n = 206/775) and Reserve agents (6.3%, n = 49/775). Ceftriaxone was the single most prescribed drug (27.7%, n = 215/775). Prescribing was overwhelmingly empirical (98.2%, n = 761/775), with documented microbiological culture or susceptibility results present in only 0.8% (n = 3/379) of patient records. Multi-drug exposure was high, with 64.4% of patients receiving two or more concurrent antimicrobials. While the private hospital achieved significantly higher chart documentation completeness than the public facility (93.9% vs. 27.3%, $p < 0.001$), AWaRe distribution and Watch-category reliance did not significantly differ between facilities ($p = 0.395$).

Conclusion

Inpatient antibiotic prescribing across tertiary hospitals in Sana'a is characterized by a heavy reliance on broad-spectrum Watch-category agents and near-total empirical treatment driven by severe diagnostic stewardship deficits. While electronic records improved documentation completeness, clinical prescribing practices remained unoptimized across both public and private sectors. Implementing routine diagnostic requisitions, local antibiograms, and structured stewardship policies is urgently needed to curb AMR in conflict-affected health systems.

1. Background

Antimicrobial resistance (AMR) is a critical global health threat, severely affecting health systems and ultimately leading to increased mortality rates [1]. Predictions from the O'Neill report estimate that drug-resistant infections could claim up to 10 million lives annually by 2050 if global consumption patterns and stewardship efforts were not significantly improved [2]. The primary reason for AMR increase is the continuous misuse and overuse of broad-spectrum antibiotics in hospital wards and community settings, especially in low- and middle-income countries (LMICs) where diagnostic infrastructure is limited and formal antimicrobial stewardship (AMS) programs are rare [3]. To promote rational antibiotic prescribing, the World Health Organization (WHO) introduced the Access, Watch, and Reserve (AWaRe) classification system [4]. Access antibiotics are recommended as first- or second-line therapies for common infections and should represent at least 60% of overall national consumption, whereas Watch and Reserve agents carry a higher risk of driving resistance and demand strict oversight [4]. Despite global initiatives, inappropriate prescribing characterized by widespread empirical treatment and high reliance on broad-spectrum "Watch" group, last-resort agents remain prevalent in LMICs, which carry higher risk of driving resistance [3, 5–7].

In fragile and conflict-affected environments like Yemen, rational prescribing becomes a greater challenge. Years of ongoing conflict, economic collapse, and infrastructure damage have shattered Yemen's healthcare system [8]. Due to critical supply shortages, limited laboratory diagnostics, and a lack of localized antibiograms, clinicians often rely on broad-spectrum coverage, extended treatment durations, and non-guideline prescribing as a default safety net to manage diagnostic uncertainty. [9, 10, 11]. Prescribing is deeply behavioral, clinicians in resource-constrained environments often practice defensive medicine, driven by the fear of poor patient outcomes and pressure from worried families [12]. This clinical guesswork is accompanied by a severe breakdown in diagnostic stewardship [13]. Without routine microbiology cultures, clinicians cannot identify causative pathogens or transition patients to targeted therapy [10, 13]. Consequently, patients remain on broad-spectrum Watch group antibiotics for extended durations, and hospitals fail to generate local antibiograms to guide future empirical protocols [11, 13].

This situation is exceptionally acute in conflict-affected settings like Yemen. Ten years of active war, economic collapse, damaged health infrastructure, and broken supply chains have destroyed medical regulatory monitoring [9]. This systemic collapse has allowed low-quality medicines to flood the market while leaving hospitals without the basic supplies needed for routine microbiology diagnostics [9, 14]. Outpatient self-medication is widespread due to weak pharmacy enforcement [15, 16], while inpatient wards exhibit heavy reliance on empirical prescribing without stewardship oversight [17]. In Yemeni hospitals, "Watch" group antibiotics most notably ceftriaxone are administrated almost automatically upon admission [15, 17]. Laboratory data from Médecins Sans Frontières (MSF) trauma units and tertiary hospitals in Sana'a demonstrates alarming resistance trends, including extended-spectrum beta-lactamase (ESBL) producing *Escherichia coli* and *Klebsiella* species, with over 60% of trauma ward infections caused by multidrug-resistant organisms [6, 14, 18].

While Yemen formulated a National Action Plan (NAP) on AMR (2022–2026) aligned with WHO guidelines, empirical clinical practices on hospital floors remain poorly documented [19]. Most existing research in Yemen focuses on community over-the-counter sales or isolated laboratory isolates, leaving a major gap in empirical data regarding ward-level inpatient prescribing, documentation completeness, and alignment with WHO AWaRe benchmarks across different health sectors [5, 16].

There is a critical lack of baseline data evaluating whether inpatient antibiotic selection in Yemeni tertiary hospitals aligns with WHO AWaRe targets or national standard treatment guidelines. Moreover, differences in prescribing patterns and documentation completeness between public and private healthcare facilities in conflict-affected urban centers like Sana'a remain rarely explored. This study evaluated inpatient antibiotic prescribing practices and their alignment with the WHO AWaRe classification across internal medicine, surgery, and intensive care units in public and private tertiary hospitals in Sana'a, Yemen. The study aimed to:

1. Quantify the distribution of prescribed antibiotics according to the WHO AWaRe classification system.
2. Determine the rates of empirical prescribing versus culture-guided therapy.
3. Compare antibiotic prescribing patterns and medical chart documentation completeness between public and private tertiary facilities.

2. Methods

2.1 Study Design

A retrospective, cross-sectional medical record audit was conducted to evaluate routine inpatient prescribing practices, diagnostic ordering habits, and chart documentation quality across acute hospital wards over a 12-month period (March 2025-March 2026).

2.2 Study Setting

The study took place at two major tertiary care hospitals in Sana'a, Yemen. These institutions were selected as primary study sites because they serve as major regional referral centers, handle heavy inpatient volumes, and manage complex infectious disease presentations. To capture systemic differences across multiple healthcare financing and administrative governance models, one public and one private tertiary facility were included:

Hospital 1 (Public Tertiary Hospital): a 500-bed university-affiliated public referral hospital characterized by high patient volume, overcrowding and relies on paper-based records.

Hospital 2 (Private Tertiary Hospital): a 100-bed private tertiary facility operating under autonomous management, serving self-paying and insured patient populations through an Electronic Health Records (EHR) system.

Within both institutions, data collection was restricted to three acute clinical departments with high antimicrobial utilization which are Intensive Care Units (ICUs), Surgery, and Internal Medicine Wards.

2.3 Study Population and Eligibility Criteria

Inpatient records from the target departments admitted between March 2025 and March 2026 were screened for inclusion.

Inclusion Criteria:

1. Admission to an ICU, surgical ward, or internal medicine ward during the study period.
2. Inpatient length of stay at least 24 hours.
3. Documentation of at least one systemic antimicrobial administrated during the stay (pediatric and adult patients included).

Exclusion Criteria:

1. Records lacking a unique patient identifier.
2. Illegible or incomplete medication administration sheets.
3. Records where antimicrobials were administered exclusively via topical, or non-systemic routes.

2.4 Sample Size and Sampling Strategy

Across the target departments in both hospitals, 26,653 inpatient admissions met the initial time frame criteria during the study period. Using Epi Info 7, a sample size of n = 379 medical records was calculated to achieve statistical validity.

Systematic random sampling was applied independently within each department using a sampling interval (K) derived from $K = N/n$:

Hospital 1 (Public, n = 175 total records):

Intensive Care Unit: n = 48 sampled (N = 3,310, sampling Interval K = 69)

Surgical Department: n = 91 sampled (N = 6,535, sampling Interval K = 70)

Internal Medicine: n = 36 sampled (N = 2,521, sampling Interval K = 70)

Hospital 2 (Private, n = 204 total records):

Intensive Care Unit: n = 8 sampled (N = 591, sampling Interval K = 74)

Surgical Department: n = 137 sampled (N = 9,642, sampling Interval K = 70)

Internal Medicine: n = 59 sampled (N = 4,136, sampling Interval K = 70)

2.5 Data Collection and Extraction Procedure

Data were collected using a structured data abstraction form developed specifically for this study. The instrument was designed following a review of existing literature on hospital-based antimicrobial utilization and chart audit methodologies, adapting key variables from relevant studies. The same standardized form was applied across paper-based records at Hospital 1 and electronic chart entries at Hospital 2. The abstraction tool captured three main categories of clinical information: patient demographics and baseline clinical parameters (age, sex, admitting hospital, clinical department, primary diagnosis, and length of stay), antimicrobial prescribing patterns (specific drug choice, dosage, route of administration, daily frequency, treatment duration, total count of concurrent systemic antimicrobials for polypharmacy assessment, and treatment intent categorized as empirical or pathogen-directed), and diagnostic and documentation practices (requisitions for microbiological culture and antimicrobial susceptibility testing, documented resistance profiles, and the explicit recording of clinical indications for antimicrobial therapy within progress notes or medication administration sheets).

2.6 Study Variables and Outcome Measures

Prescribed antibiotics were classified according to the World Health Organization (WHO) AWaRe framework categorizing into Access (narrow-spectrum first and second-line drugs with lower resistance potential), Watch (broad-spectrum agents with higher selection pressure for resistance), and Reserve (last-resort options intended strictly for multidrug-resistant pathogens) groups. Primary outcome measures included the proportions of Access, Watch, and Reserve prescriptions evaluated against the global WHO target benchmark of at least 60% Access category consumption, the rate of empirical versus culture-guided therapy, the diagnostic stewardship rate (defined as the percentage of antibiotics ordered which were supported by a documented microbiological culture requisition), and chart documentation completeness (defined as the percentage of patient files containing an explicitly stated clinical indication for antibiotic therapy).

2.7 Data Management and Statistical Analysis

Data were coded, entered, and analyzed using IBM SPSS Statistics (version 26.0) Descriptive statistics summarized baseline sample metrics, presenting categorical variables as absolute frequencies (*n*) and percentages (%), and continuous variables as means with Standard Deviations (SD).

Comparisons between public and private facilities and across clinical departments were conducted using Pearson's Chi-square (χ^2) test or Fisher's exact test for categorical variables. Cross-tabulations were generated to evaluate drug-specific prescribing frequencies and polypharmacy rates. Statistical significance was set as $p < 0.05$ (two-tailed).

2.7 Ethical Considerations

Ethical and administrative approvals were granted by the Ministry of Health and Environment and executive leadership at both hospitals. Informed consent was waived due to the retrospective, non-

interventional nature of the chart review. Patient confidentiality was protected by removing personal identifiers and assigning unique alphanumeric study codes to all records prior to analysis.

3. Results

3.1 Characteristics of the Study Population

A total of 379 patient records were reviewed from the selected hospitals. The study included records from both public and private hospitals. Hospital 2 (private hospital) represented 53.8% (*n* = 204) of the reviewed records, while Hospital 1 (public hospital) accounted for 46.2% *(n* = 175). Most patients were from the surgery wards, representing 60.2% (*n* = 228) of the study population. Internal medicine wards accounted for 25.1% (*n* = 95), while intensive care units (ICU) represented 14.8% (*n* = 56).

The age of patients ranged from 1 month to 100 years, with a mean age of 38.6 ± 19.6 years. Male patients represented 52.5% (n = 199) of the sample while female patients represented 47.5% (*n* = 180).

Regarding treatment outcomes, most patients were discharged from the hospital 87.3% (*n* = 331). A mortality rate of 9.5% (*n* = 36) was observed. A small number of patients were discharged against medical advice 1.1% (*n* = 4), while 2.1% (*n* = 8) had undocumented outcomes.

Table 1
Characteristics of the Study Population

Baseline Characteristics	Category	Frequency (n)	Valid Percentage (%)
Hospital Facility	Public Hospital (1)	175	46.2%
	Private Hospital (2)	204	53.8%
Clinical Department	Intensive Care Unit (ICU)	56	14.8%
	Surgery Wards	228	60.1%
	Internal Medicine Wards	95	25.1%
Patient Gender	Male	199	52.5%
	Female	180	47.5%
Clinical Outcome	Discharged	331	87.3%
	Dead	36	9.5%
	Discharged against Medical Advice (DAMA)	4	1.1%
	Undocumented/ Not mentioned	8	2.1%

3.2 Documentation of Infection Types

Most patient records did not contain a clearly documented infection diagnosis. Undocumented infection types represented 95.0% (*n* = 360) of reviewed records. Among the documented infections, chest infections were the most common 4.0% (*n* = 15), followed by urinary tract infections (0.8% (*n* = 3). One patient record documented a generalized bacterial infection 0.3% (*n* = 1). These findings indicate limited documentation of infection diagnosis within patient records.

Table 2
Distribution of Infection Types

Infection Type Classification	Frequency (n)	Valid Percentage (%)	Cumulative Percentage (%)
Undocumented	360	95.0%	95.0%
Chest Infection	15	4.0%	99.0%
Urinary Tract Infection (UTI)	3	0.8%	99.8%
Generalized Bacterial Infection	1	0.3%	100.0%
Total	379	100%	

3.3 Overall Antibiotic Prescribing Patterns

A total of 775 antibiotic prescriptions were reviewed across the selected hospitals, within these prescriptions 29 different antibiotics were identified. Table 3 lists the 29 antibiotics that were identified. Ceftriaxone was the most commonly described antibiotic, accounting for 27.7% (*n* = 215). Metronidazole represented 11.9% (*n* = 92), followed by Levofloxacin at 8.6% (*n* = 67). Other commonly prescribed antibiotics included Amoxicillin/Clavulanate 6.6% (*n* = 51), Cefuroxime 6.2% (*n* = 48), Meropenem 4.6% (*n* = 36), and Moxifloxacin 4.5% (*n* = 35).

Table 3
Overall Antibiotic Prescribing Patterns (N = 775)

Antibiotic	Frequency (n)	Percentage %
Ceftriaxone	215	27.7%
Metronidazole	92	11.9%
Levofloxacin	67	8.6%
Amoxicillin/Clavulanate	51	6.6%
Cefuroxime	48	6.2%
Meropenem	36	4.6%
Moxifloxacin	35	4.5%
Tazobactam/Piperacillin	29	3.7%
Vancomycin	24	3.1%
Azithromycin	22	2.8%
Cefixime	18	2.3%
Clindamycin	18	2.3%
Ciprofloxacin	16	2.1%
Doxycycline	16	2.1%
Amikacin	14	1.8%
Gentamicin	14	1.8%
Linezolid	13	1.7%
Clarithromycin	9	1.2%
Imipenem/Cilastatin	8	1.0%
Sulfamethoxazole/Trimethoprim	8	1.0%
Cefepime	8	1.0%
Other Minor Agents*	15	2.0%
Total	775	100.0%

*Note: “Other Minor Agents” include Ampicillin (n = 3), cefaclor (n = 1). Cefoperazone (n = 1), Cefotaxime (n = 3), Cefpodoxime (n = 2), Nitrofurantoin (n = 3), and Tetracycline (n = 1).

3.4 Number of Antibiotic Prescribed per Patient

When looking at individual antibiotic exposure, the vast majority of patients were put on multiple drugs during their admission. A two-antibiotic regimen turned out to be the most frequent setup, accounting for 40.1% (*n* = 152). Single-antibiotic use came in just behind that, making 35.6% (*n* = 135). Patients receiving three antibiotics accounted for 14.2% (*n* = 54). A smaller proportion received four or more antibiotics 10.1% (*n* = 38), with a few extreme cases receiving up to eight antibiotics. The mean number of antibiotics per patient indicates moderate to high antibiotic exposure across hospital admissions.

Table 4
Number of Antibiotic Prescribed per Patient

Number of Antibiotics	Frequency (n)	Percentage (%)	Cumulative (%)
1	135	35.6	35.6
2	152	40.1	75.7
3	54	14.2	90.0
4	25	6.6	96.6
5	8	2.1	98.7
6	3	0.8	99.5
7	1	0.3	99.7
8	1	0.3	100.0
Total	379	100.0	—

3.5 Most Common Antibiotics by Diagnosis Group

Ceftriaxone was the most commonly used antibiotic across almost all diagnosis groups, especially in respiratory, gastrointestinal, neurological, and obstetric conditions. This shows a strong reliance on this broad-spectrum antibiotic in routine treatment. Metronidazole was mainly used for gastrointestinal and gynecological conditions, reflecting its role in infections involving anaerobic bacteria. Ciprofloxacin and levofloxacin were also widely used in urinary, respiratory, and gastrointestinal infections.

Strong antibiotics like meropenem and vancomycin were mostly used in severe cases such as sepsis and neurological diseases, but their use in some less severe conditions may suggest overuse of broad-spectrum antibiotics.

Table 5
Most Frequently Prescribed Antibiotics by Diagnosis Group

Diagnosis Group	Top 5 Antibiotics
Cardiovascular Diseases	Ceftriaxone, Ciprofloxacin, Amikacin, Metronidazole, Cefotaxime
Endocrine & Metabolic Disorders	Ceftriaxone, Ciprofloxacin, Cefuroxime, Cefixime, Meropenem
ENT & Head and Neck	Ceftriaxone, Amoxicillin/Clavulanate, Cefuroxime, Levofloxacin, Azithromycin
Gastrointestinal & Hepatobiliary	Metronidazole, Ceftriaxone, Cefuroxime, Ciprofloxacin, Meropenem
Genitourinary & Urological Diseases	Levofloxacin, Ceftriaxone, Amoxicillin/Clavulanate, Cefixime, Ciprofloxacin
Hematology & Oncology	Ceftriaxone, Levofloxacin, Azithromycin, Metronidazole, Ciprofloxacin
Infectious Disease	Doxycycline, Meropenem, Ceftriaxone, Vancomycin, Ciprofloxacin
Musculoskeletal Disorders	Cefuroxime, Ceftriaxone, Gentamicin, Ciprofloxacin, Amoxicillin/Clavulanate
Neurological Diseases	Ceftriaxone, Meropenem, Vancomycin, Levofloxacin, Doxycycline
Obstetrics & Gynecology	Ceftriaxone, Cefuroxime, Metronidazole, Cefixime, Gentamicin
Ophthalmology	Ceftriaxone, Amoxicillin/Clavulanate, Cefixime, Ciprofloxacin, Cefuroxime
Respiratory Diseases	Azithromycin, Ceftriaxone, Cefixime, Levofloxacin, Doxycycline
Sepsis	Ceftriaxone, Piperacillin–Tazobactam, Meropenem, Metronidazole, Vancomycin
Skin & Soft Tissue Infection	Clindamycin, Ceftriaxone, Levofloxacin, Amoxicillin/Clavulanate, Metronidazole
Trauma & Orthopedic Injuries	Ceftriaxone, Amoxicillin/Clavulanate, Meropenem, Gentamicin, Ciprofloxacin
Unknown	Ceftriaxone, Cefuroxime, Ciprofloxacin, Metronidazole, Levofloxacin

3.6 WHO AWaRe Classification of Individual Antibiotics

All antibiotics were classified according to the WHO AWaRe classification system. Watch antibiotics accounted for the majority of prescriptions 67.1% (*n* = 520), followed by Access antibiotics 26.6% (*n* = 206), while Reserve antibiotics represented 6.3% (*n* = 49). At the drug level, ceftriaxone was the most frequently prescribed antibiotic and a major contributor to the Watch Category. Other commonly used Watch antibiotics included levofloxacin, cefuroxime, moxifloxacin, and piperacillin/tazobactam. Access

antibiotics were less frequently used and mainly included metronidazole and amoxicillin/clavulanate. Reserve antibiotics such as meropenem and linezolid were also present, though at lower frequencies.

Table 6
AWaRe Classification by Individual Antibiotic (N = 775)

Antibiotic	Access n (%)	Watch n (%)	Reserve n (%)	Total n (%)
Amikacin	14 (100.0)	0 (0.0)	0 (0.0)	14 (100.0)
Amoxicillin/Clavulanate	51 (100.0)	0 (0.0)	0 (0.0)	51 (100.0)
Ampicillin	3 (100.0)	0 (0.0)	0 (0.0)	3 (100.0)
Azithromycin	0 (0.0)	22 (100.0)	0 (0.0)	22 (100.0)
Cefaclor	0 (0.0)	1 (100.0)	0 (0.0)	1 (100.0)
Cefepime	0 (0.0)	8 (100.0)	0 (0.0)	8 (100.0)
Cefixime	0 (0.0)	18 (100.0)	0 (0.0)	18 (100.0)
Cefoperazone	0 (0.0)	1 (100.0)	0 (0.0)	1 (100.0)
Cefotaxime	0 (0.0)	3 (100.0)	0 (0.0)	3 (100.0)
Cefpodoxime	0 (0.0)	2 (100.0)	0 (0.0)	2 (100.0)
Ceftriaxone	0 (0.0)	215 (100.0)	0 (0.0)	215 (100.0)
Cefuroxime	0 (0.0)	48 (100.0)	0 (0.0)	48 (100.0)
Ciprofloxacin	0 (0.0)	16 (100.0)	0 (0.0)	16 (100.0)
Clarithromycin	0 (0.0)	9 (100.0)	0 (0.0)	9 (100.0)
Clindamycin	18 (100.0)	0 (0.0)	0 (0.0)	18 (100.0)
Doxycycline	16 (100.0)	0 (0.0)	0 (0.0)	16 (100.0)
Gentamicin	0 (0.0)	14 (100.0)	0 (0.0)	14 (100.0)
Imipenem/Cilastatin	0 (0.0)	8 (100.0)	0 (0.0)	8 (100.0)
Levofloxacin	0 (0.0)	67 (100.0)	0 (0.0)	67 (100.0)
Linezolid	0 (0.0)	0 (0.0)	13 (100.0)	13 (100.0)
Meropenem	0 (0.0)	36 (100.0)	0 (0.0)	36 (100.0)
Metronidazole	92 (100.0)	0 (0.0)	0 (0.0)	92 (100.0)
Moxifloxacin	0 (0.0)	35 (100.0)	0 (0.0)	35 (100.0)
Nitrofurantoin	3 (100.0)	0 (0.0)	0 (0.0)	3 (100.0)
Sulfamethoxazole/Trimethoprim	8 (100.0)	0 (0.0)	0 (0.0)	8 (100.0)
Piperacillin/Tazobactam	0 (0.0)	29 (100.0)	0 (0.0)	29 (100.0)
Tetracycline	1 (100.0)	0 (0.0)	0 (0.0)	1 (100.0)

Antibiotic	Access n (%)	Watch n (%)	Reserve n (%)	Total n (%)
Vancomycin	0 (0.0)	0 (0.0)	24 (100.0)	24 (100.0)
Total	206 (26.6)	520 (67.1)	49 (6.3)	775 (100.0)

3.7 Overall Distribution of WHO AWaRe Categories

All prescribed antibiotics were classified according to the WHO AWaRe classification system. Watch antibiotics represented the majority of prescriptions at 67.1% (*n* = 520). Access antibiotics accounted for 26.6% (*n* = 206), while Reserve antibiotics represented 6.3% (*n* = 49).

Table 7
Overall Distribution of WHO AWaRe Categories

WHO AWaRe Group	Frequency (n)	Valid Percent (%)	Cumulative Percent (%)
Watch	520	67.1%	67.1%
Access	206	26.6%	93.7%
Reserve	49	6.3%	100.0%
Total	775	100.0%	—

3.8 Distribution of WHO AWaRe Categories Across Diagnosis Groups

Across all diagnosis groups, Watch antibiotics were used the most 67.1%, followed by Access 26.6% and Reserve antibiotics 6.3%. High use of Watch antibiotics was seen in respiratory, hematology & oncology, endocrine, and obstetrics/gynecology cases, showing a strong reliance on broad-spectrum antibiotics. Gastrointestinal cases had relatively more Access antibiotics compared to other groups. Reserve antibiotics were used less often overall, but were more common in neurological and trauma cases, likely because these are more severe conditions.

Overall, the results show a heavy dependence on Watch antibiotics in most conditions, which may reflect empirical prescribing and raises concerns about possible overuse and antimicrobial resistance.

Table 8
Distribution of WHO AWaRe Categories by Diagnosis Group

Diagnosis Group	Access n (%)	Reserve n (%)	Watch n (%)	Total
Cardiovascular Diseases	9 (23.7%)	3 (7.9%)	26 (68.4%)	38
Endocrine & Metabolic Disorders	2 (14.3%)	1 (7.1%)	11 (78.6%)	14
ENT & Head and Neck	6 (23.1%)	0 (0.0%)	20 (76.9%)	26
Gastrointestinal & Hepatobiliary	70 (37.8%)	4 (2.2%)	111 (60.0%)	185
Genitourinary & Urological Diseases	23 (27.4%)	5 (6.0%)	56 (66.7%)	84
Hematology & Oncology	7 (16.3%)	1 (2.3%)	35 (81.4%)	43
Infectious Disease	1 (50.0%)	1 (50.0%)	0 (0.0%)	2
Musculoskeletal Disorders	7 (41.2%)	0 (0.0%)	10 (58.8%)	17
Neurological Diseases	6 (12.0%)	12 (24.0%)	32 (64.0%)	50
Obstetrics & Gynecology	21 (24.1%)	1 (1.1%)	65 (74.7%)	87
Ophthalmology	1 (50.0%)	0 (0.0%)	1 (50.0%)	2
Respiratory Diseases	13 (13.1%)	4 (4.0%)	82 (82.8%)	99
Sepsis	9 (33.3%)	4 (14.8%)	14 (51.9%)	27
Skin & Soft Tissue Infection	5 (35.7%)	1 (7.1%)	8 (57.1%)	14
Trauma & Orthopedic Injuries	25 (30.1%)	12 (14.5%)	46 (55.4%)	83
Unknown	1 (25.0%)	0 (0.0%)	3 (75.0%)	4
Total	206 (26.6%)	49 (6.3%)	520 (67.1%)	775

3.9 Antimicrobial Stewardship (AMS) Process Quality Indicators

Several antimicrobial stewardship indicators were assessed, including prescribing approach, prescription documentation, culture testing, and stewardship justification.

1. **Empirical Therapy vs. Targeted Treatment**

Most antibiotic prescriptions were empirical therapies, accounting for 98.2% (*n* = 761) of prescriptions. Only 1.8% (*n* = 14) were targeted therapies based on confirmed microbiological findings.

1. **Culture Testing and Resistance Documentation**

Microbiological culture testing and resistance documentation were rarely reported. Only 0.8% (*n* = 3) of patient's records included documented culture or susceptibility results, while 99.2% (*n* = 376) had no

documented culture testing.

1. **Prescription Documentation**

Complete antibiotic documentation, including drug name, dose, route of administration and duration, was present in 65.5% (*n* = 508) of prescription. However, 34.5% (*n* = 267) of prescriptions lacked complete documentation.

1. **Stewardship Justification**

None of the reviewed prescriptions included formal documentation justifying antibiotic selection or reference to antimicrobial stewardship guidelines.

Table 9
Antimicrobial Stewardship Process Indicators

Stewardship Indicator	Category	Frequency (n)	Vail Percentage %
Prescribing Approach	Empirical Therapy	761	98.2%
	Targeted Therapy	14	1.8%
Prescription Documentation	Documented	508	65.5%
	Undocumented	267	34.5%
Stewardship Justification	Documented	0	0.0%
	Undocumented	775	100.0%
Culture and Resistance documentation	Documented	3	0.8%
	Undocumented	376	99.2%

3.10 Antibiotics Dose Frequency and Treatment Durations

The overall mean antibiotic frequency was (1.99 ± 0.78) doses per day. The mean treatment duration was (6.27 ± 4.21) days. Ceftriaxone showed a mean frequency of 1.89 doses per day and a mean duration of 5.08 days. Metronidazole had a mean frequency of 2.57 doses per day with a mean duration of 4.91 days. Longer treatment durations were observed for some antibiotics, including Nitrofurantoin 16.67 days, Doxycycline 10.13 days, and Clarithromycin 9.56 days.

Table 10
Antibiotic Dose Frequency and Treatment Duration

Antibiotic Agent	Frequency N	Mean Doses/Day ± SD	Duration N	Mean Duration (Days) ± SD
Ceftriaxone	213	1.89 ± 0.38	205	5.08 ± 3.88
Metronidazole	92	2.75 ± 0.59	89	4.91 ± 2.97
Levofloxacin	66	1.03 ± 0.17	65	7.71 ± 3.49
Amoxicillin/Clavulanate	51	2.04 ± 0.34	51	7.35 ± 2.78
Cefuroxime	47	2.06 ± 0.97	48	5.10 ± 2.21
Meropenem	35	2.66 ± 0.64	34	7.97 ± 5.13
Moxifloxacin	35	1.00 ± 0.00	35	6.60 ± 5.04
Piperacillin/Tazobactam	29	2.86 ± 0.52	26	7.69 ± 4.17
Vancomycin	23	2.22 ± 0.60	22	6.91 ± 4.34
Azithromycin	22	1.14 ± 0.35	22	5.05 ± 2.30
Clindamycin	18	2.94 ± 0.94	17	9.41 ± 7.01
Cefixime	18	1.33 ± 0.49	18	6.11 ± 1.71
Doxycycline	16	1.88 ± 0.50	16	10.13 ± 6.86
Ciprofloxacin	15	1.87 ± 0.35	15	6.07 ± 3.49
Gentamicin	14	1.93 ± 0.92	14	4.57 ± 2.38
Amikacin	14	1.50 ± 0.52	14	5.64 ± 2.90
Linezolid	13	2.00 ± 0.58	13	7.62 ± 5.03
Clarithromycin	8	1.88 ± 0.35	9	9.56 ± 2.01
Sulfamethoxazole/Trimethoprim	8	1.88 ± 0.35	8	9.25 ± 8.57
Imipenem/Cilastatin	8	2.88 ± 1.64	8	8.75 ± 6.78
Cefepime	8	2.38 ± 0.74	8	5.25 ± 1.75
Other antibiotics*	13	—	13	—
Overall	767	1.99 ± 0.78	751	6.27 ± 4.22

Note: N represents the number of prescriptions with available data for dose frequency and treatment duration, respectively. Differences between frequency and duration sample sizes reflect missing data in some patient records. Other antibiotics include Ampicillin (n = 3), Nitrofurantoin (n = 3), Cefpodoxime (n = 2), Cefotaxime (n = 2), Tetracycline (n = 1), Cefaclor (n = 1), and Cefoperazone (n = 1). Individual summary statistics are not presented due to very small sample sizes.

3.11 Comparative Analysis Between Hospitals

3.11.1 Distribution of Prescriptions Across Clinical Departments

Hospital 1 (public hospital) accounted for 330 antibiotic prescriptions, while hospitals 2 (private hospital) accounted for 445 prescriptions. In hospital 1, most prescriptions originated from surgery wards 53.9% (*n* = 178), and internal medicine wards 20.0% (*n* = 66). In Hospital 2, surgery wards represented the largest proportion of prescriptions 75.5% (*n* = 336), followed by internal medicine wards 20.9% (*n* = 89) and ICU wards 4.5% (n = 20).

Table 11
Distribution of Prescriptions Across Clinical Departments

Hospital Facility	ICU Wards n (%)	Internal Medicine n (%)	Surgery n (%)	Total n (%)
Hospital 1 (Public)	86 (26.1)	66 (20.0)	178 (53.9)	330 (100.0)
Hospital 2 (Private)	20 (4.5)	89 (20.0)	336 (75.5)	445 (100.0)
Total	106 (13.7)	155 (20.0)	514 (66.3)	775 (100.0)

3.11.2 Distribution of WHO AWaRe Categories by Hospital

No statistically significant association was found between hospitals and type of WHO AWaRe categories ($\chi^2 = 1.855$, df = 2, p = 0.395). Watch antibiotics remained the most commonly prescribed category in both settings.

Table 12
Distribution of WHO AWaRe Categories by Hospital (N = 775).

Hospital	Access n (%)	Watch n (%)	Reserve n (%)	Total
Hospital 1	90 (27.3)	215 (65.2)	25 (7.6)	330 (100.0)
Hospital 2	116 (26.1)	305 (68.5)	24 (5.4)	445 (100.0)
Total	206 (26.6)	520 (67.1)	49 (6.3)	775 (100.0)

3.11.3 Distribution of WHO AWaRe Categories Across Clinical Departments

We found a highly statistically significant association between the clinical department and WHO AWaRe category selection ($\chi^2 = 48.101$, df = 4, p < 0.001). While Watch Antibiotics were the top choice across all wards, Reserve antibiotics were used significantly more often in the ICU than in the internal medicine or surgery.

Table 13
Distribution of WHO AWaRe Categories Across Clinical Department

Department	Access n (%)	Reserve n (%)	Watch n (%)	Total n (%)
ICU	17 (16.0)	20 (18.9)	69 (65.1)	106 (100.0)
Internal Medicine	27 (17.4)	7 (4.5)	121 (78.1)	155 (100.0)
Surgery	162 (31.5)	22 (4.3)	330 (64.2)	514 (100.0)
Total	206 (26.6)	49 (6.3)	520 (67.1)	775 (100.0)

3.11.4 Comparison of Prescription Documentation Completeness Between Hospitals

A statistically significant association was found between hospital type and prescription documentation completeness ($\chi^2 = 372.846$, df = 1, $p < 0.001$). Hospital 2 demonstrated higher rates of complete documentation, with 93.9% (*n* = 418) of prescriptions fully documented. In comparison 72.7% (*n* = 240) of prescriptions in Hospital 1 lacked complete documentation.

Table 14
Documentation Competence by Hospital

Hospital	No Documentation n (%)	Complete Documentation n (%)	Total n (%)
Hospital 1	240 (72.7)	90 (27.3)	330 (100.0)
Hospital 2	27 (6.1)	418 (93.9)	445 (100.0)
Total	**267 (34.5)**	**508 (65.5)**	**775 (100.0)**

4. Discussion

Antibiotic Prescribing Patterns and WHO AWaRe Compliance

This study found that broad-spectrum antibiotics were heavily used in both hospitals, with Ceftriaxone being the most common prescription. Most of the prescribed drugs fell under the “Watch” category, which shows low adherence to the WHO AWaRe guidelines that recommend “Access” antibiotics account for at least 60% of overall consumption. Reserve antibiotics were used at a low overall level (6.3%), but were mainly observed in more severe conditions such as neurological diseases and trauma-related cases. Their use in some non-critical conditions may indicate occasional escalation to last-line agents without strong microbiological confirmation. These results match previous research from hospital settings in Yemen, where cephalosporins and other broad-spectrum drugs are regularly given to inpatients [3,15,17,16,20,]

Several factors explain why there is high reliance on Watch antibiotics. Ceftriaxone is widely available, cheap, and easy to administer. Doctors also rely on it as an immediate empirical treatment for sever

infections before any laboratory results come back. When lab support is slow or unavailable, clinicians choose broad-spectrum options to cover all bases and protect critically ill patients. Moreover, these hospitals lack local antibiograms and strong stewardship monitoring, so using these antibiotics has simply become the default habit over time.

Extensive Empirical Therapy and Diagnostic Stewardship Deficiencies

A critical finding of this study is the extreme disconnect between clinical prescribing and microbiological diagnostics. Pathogen-directed therapy guided by culture and antimicrobial susceptibility test (AST) was documented in only 0.8% of patient charts. These findings confirm a systemic diagnostic stewardship deficit, leaving virtually all inpatient antimicrobial regimens completely empirical.

While the WHO antimicrobial stewardship toolkit highlights culture and susceptibility testing as vital for rational antibiotic use and targeted therapy [13], many healthcare facilities in LMIC settings still struggle to use these tests routinely. The situation observed in this study matches international data from other LMIC healthcare environments, where widespread empirical prescribing is tied to short-staffed labs, financial constraints, and weak microbiological surveillance networks [10, 11, 13]. The lack of routine testing prevents hospitals from building local antibiograms [4, 13], leaving prescribers without local susceptibility data. Consequently, drug selection relies entirely on individual clinician experience rather than evidence-based institutional protocols.

Unmonitored empirical reliance on Watch category agents without diagnostic oversight carries severe epidemiological risks, directly driving local antimicrobial resistance (AMR). Prior surveillance studies in Yemeni tertiary hospitals have already documented alarming rates of multidrug-resistant Gram-negative pathogens, including extended-spectrum β-lactamases-(ESBL) producing organisms [5, 6, 7]. Without systematic diagnostic stewardship and local resistance tracking, health facilities cannot update empirical treatment guidelines to match shifting resistance profiles.

Sectoral Record-Keeping Infrastructures and Audit Feasibility

The audit revealed a major difference in documentation quality between the two sectors, which directly affected how easily patient files could be audited. The public hospital relied entirely on paper-based charts, where heavy patients load and limited resources led to frequent missing information, unrecorded clinical indications, and incomplete drug entries. In contrast, the private facility used an electronic health record system that encouraged complete entries, resulting in a much higher rate of documented indications compared to the public site (93.9% vs 27.3). Ultimately, poor paper record keeping makes clinical auditing far more labor-intensive and makes it harder to track drug use accurately or build automated surveillance systems.

High Polypharmacy Rates and Multi-Drug Exposure

A significant quantitative finding was the high rate of multi-drug exposure 64.45 of audited patients received two or more systemic antimicrobials concurrently. This reliance on combination empirical

therapy highlights a pattern of defensive prescribing, where clinicians use multiple broad-spectrum drugs simultaneously to ensure coverage. In the absence of routine 48-to72 hour antibiotic timeouts or stepdown protocols, patients rarely transition from broad-spectrum combinations to targeted monotherapy. Simply distributing printed prescribing guidelines is rarely sufficient to modify these patterns, effective reduction of Watch-category overuse requires pairing educational initiatives with active, prospective audit-and-feedback [3].

Monitoring Infrastructure Deficits and AMR Epidemiological Blindspots

Neither facility possess the baseline infrastructure required to track defined daily dose (DDD), monitor key performance indicators, or establish standardized drug consumption trends overtime. In high-AMR environments such as Yemeni tertiary hospitals where multidrug-resistant pathogens are prevalent [21, 22], this lack of systematic tracking leaves a major epidemiological blindspot. This data gap directly harms clinical oversight. Without tracking systems or prospective audit-and-feedback loops, hospitals cannot assess the selection pressure driving resistance, monitoring heavy reliance on Watch category antibiotics, evaluates stewardship measures, or spot emerging resistance increase in high-risk wards.

Strengths and Limitations

This study has several notable strengths. Utilizing the WHO AWaRe framework alongside standardized drug utilization indicators adapted from published literature allows direct comparison of these local findings with international benchmarks. Furthermore, auditing both public and private tertiary centers provides valuable insight into prescribing practices across differing operational financing, and recordkeeping models in Sana'a. Finally, applying systematic random sampling across high-utilization clinical departments, including ICUs, surgical wards, and internal medicine departments ensured a representative sample of acute inpatient care.

However, several limitations should be considered when interpreting these findings. First, the retrospective chart review design relied entirely on documented records, clinical rationales discussed verbally during ward rounds may have been omitted from written charts, particularly in the paper-based public hospital. Second, because data collection was restricted to two tertiary centers in urban Sana'a, these findings may not fully generalize to rural district hospitals or primary health centers. Finally, the audit evaluated prescribing patterns and documentation completeness during the inpatient stay, but did not track post-discharge clinical outcomes, treatment failure rates, or long-term mortality.

5. Conclusion

This quantitative audit demonstrates that inpatient antibiotic prescribing across tertiary hospitals in Sana'a is characterized by a heavily reliance on broad-spectrum Watch category agents and near total empirical treatment. The low alignment with WHO AWaRe guidelines driven primarily by widespread ceftriaxone utilization and an almost complete absence of microbiological culture requisitions, highlights a profound diagnostic stewardship deficit. While private sector electronic health records significantly

improved chart completeness and indication logging compared to public paper charts, enhanced record-keeping alone did not limit broad-spectrum overuse. Both facilities demonstrated identical clinical prescribing patterns regardless of operational or financing models. Addressing these prescribing practices will require establishing routine diagnostic requisitions for acute admissions, implementing electronic order prompts, introducing standardized paper charts. Establishing these baseline audit mechanisms is an essential first step toward monitoring local consumption and reducing antimicrobial resistance in Yemen's tertiary facilities.

Abbreviations

WHO
World Health Organization
AMR
Antimicrobial Resistance
AMS
Antimicrobial Stewardship
AST
Antimicrobial Susceptibility Testing
AWaRe
World Health Organization Antibiotic Classification (Access, Watch, and Reserve)
LMICs
Low- and Middel-Income Countries
ESBL
Extended-Spectrum Beta-Lactamase
MSF
Médecins Sans Frontières
NAP
National Action Plan
MDR
Multidrug-resistance
SPSS
Statistical Package for the Social Sciences
HER
Electronic Health Records
ICU
Intensive Care Unit
UTI
Urinary Tract Infection
ENT
Ear, Nose, Throat

Declarations

Ethics approval and consent to participate: Ethical and administrative approvals were granted by the Ministry of Health and Environment, Sana’a, Yemen, and executive leadership at both participating hospital facilities. Informed consent was waived by the ethics committee due to the retrospective, non-interventional design of the chart audit and the anonymized handling of patient records.

Consent for Publication Not applicable.

Availability of data and materials

The data used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing Interests

The author declare that they have no competing interests.

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Authors’ Contributions AMDA conceptualized and designed the study, coordinated data extraction, conducted statistical analysis, and drafted the manuscript. HZA contributed to methodology design, analytical framework structuring, institutional site access, administrative oversight, and critical revision of the draft. PM provided academic supervision and advisory guidance on the research protocol. EA facilitated site access, provided administrative oversight, and reviewed the draft. All authors read and approved the final manuscript.

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