



## The Role of the Hospital Pharmacist in Monitoring and Rationalizing the use of Antimicrobials

Kasamba Ilunga Eric

### Abstract

**Introduction:** Antibiotic resistance poses a major threat to public health, particularly in resource-limited countries where empirical antibiotic therapy and limited access to microbiological testing contribute to inappropriate prescribing. In the Democratic Republic of Congo, data on the role of hospital pharmacists in the rationalization of antibiotic use remain limited.

**Methods:** A cross-sectional observational study was conducted in several public and private healthcare facilities in Lubumbashi. A total of 903 antibiotic prescriptions were evaluated. Factors associated with inappropriate prescribing were analyzed using multivariate logistic regression. A pharmaceutical intervention score (0–5) was developed to quantify the pharmacist's clinical involvement. The model's performance was assessed using the area under the ROC curve (AUC), the Hosmer–Lemeshow test, and Nagelkerke's pseudo- $R^2$ .

**Results:** The rate of inappropriate prescribing was 11.1%. The absence of an antibiogram (OR<sub>a</sub> = 4.72; 95% CI: 2.95–7.54;  $p < 0.001$ ) and empirical antibiotic therapy (OR<sub>a</sub> = 4.61; 95% CI: 2.89–7.34;  $p < 0.001$ ) were major independent predictors of inappropriate prescribing. Each additional point in the pharmaceutical score reduced the risk by 62% (OR = 0.38; 95% CI: 0.29–0.49;  $p < 0.001$ ), while a high score (4–5) decreased the risk by approximately 85%. The model demonstrated excellent discrimination (AUC = 0.87) and good calibration ( $p = 0.55$ ;  $R^2 = 0.41$ ).

**Conclusion:** Structured pharmacist intervention is a powerful and independent determinant of prescription quality, even in contexts of limited diagnostic resources. Its institutional integration represents a key strategic lever for strengthening Antimicrobial Stewardship programs in Lubumbashi.

**Keywords:** Anti-Bacterial Agents, Drug Resistance, Microbial, Antimicrobial Stewardship, Pharmacists, Inappropriate Prescribing, Hospitals

### Introduction

Antibiotic resistance is currently one of the greatest threats to global public health[1]. The World Health Organization (WHO) estimates that, without urgent action, infections caused by multidrug-resistant bacteria could become a leading cause of death in low- and middle-income countries[2,3]. In sub-Saharan Africa, this problem is exacerbated by inappropriate antibiotic prescribing, self-medication, the lack of antibiograms, and poor adherence to treatment guidelines[4-6]. In the Democratic Republic of Congo, and particularly in the city of Lubumbashi, healthcare facilities face significant structural challenges: limited access to microbiological testing, high

#### Affiliation:

University of Lubumbashi, Faculty of Medicine, Department of Biomedical Sciences

#### \*Corresponding author:

Kasamba Ilunga Eric, University of Lubumbashi, Faculty of Medicine, Department of Biomedical Sciences.

**Citation:** Kasamba Ilunga Eric. The Role of the Hospital Pharmacist in Monitoring and Rationalizing the use of Antimicrobials. Archives of Microbiology and Immunology. 9 (2026): 80-90.

**Received:** April 30, 2026

**Accepted:** May 04, 2026

**Published:** May 19, 2026

patient demand, overburdened prescribers, and insufficient integration of clinical pharmacists into the therapeutic decision-making process [7]. Several studies have shown that irrational prescribing patterns (prolonged empirical prescribing, unjustified combinations, inappropriate dosages) promote the emergence and spread of bacterial resistance [8].

Pharmacists, as medication professionals, play a key role in promoting the appropriate use of antibiotics [9,10]. Their involvement in prescription validation, pharmaceutical analysis, antibiotic therapy monitoring, and prescriber awareness training constitutes a major lever in the fight against antibiotic resistance [11-13]. However, this role remains insufficiently documented and valued in healthcare facilities in Lubumbashi. This study aims to analyze antibiotic prescribing patterns in health facilities in Lubumbashi, to identify factors associated with inappropriate prescriptions and to highlight the strategic role of the hospital pharmacist in the fight against antibiotic resistance.

## Methodology

### Type and framework of the study

This is an **analytical cross-sectional observational study**, conducted in several public and private health facilities in the city of Lubumbashi.

### Study population

Antibiotic prescriptions issued to patients treated in selected healthcare facilities were included. Each prescription was evaluated using a standardized questionnaire.

### Calculating the minimum size

#### Schwartz formula

$$n = \frac{Z^2 \times p(1 - p)}{d^2}$$

Standard assumptions:

- $Z = 1.96$  (95% CI)
- $p = 0.50$  (theoretical maximum prevalence)
- $d = 0.05$  (margin of error 5%)

#### Calculation

$$n = \frac{(1,96)^2 \times 0,50(1 - 0,50)}{(0,05)^2}$$

$$n = \frac{3,8416 \times 0,25}{0,0025}$$

$$n = \frac{0,9604}{0,0025}$$

$$n = 384,16$$

### Adjustment for non-response (10%)

$$n_{ajusté} = \frac{384}{0,9}$$

$$n_{ajusté} = \frac{384}{0,9}$$

Actual number: **903 prescriptions**

### Inclusion criteria

- Prescriptions containing  $\geq 1$  antibiotic
- Hospitalized patients
- Complete prescription (molecule, dose, duration)
- Defined study period

### Exclusion criteria

- Outpatient prescriptions
- Incomplete prescriptions
- Patients transferred without complete data
- Unreadable data

### Variables studied

#### Dependent variable:

- o Prescription generally appropriate (Yes / No)

#### Independent variables:

- o Availability of the antibiogram
- o Compliance with WHO/MSP recommendations
- o Type of antibiotic therapy (empirical vs. targeted)
- o Antibiotic combination
- o Performing a microbiological sampling

### Data collection

Data were collected using a structured questionnaire assessing diagnosis, choice of antibiotic, dosage, duration, existence of an antibiogram and justification of combinations.

### Statistical analysis

- **Univariate** analysis: frequencies and percentages
- **Bivariate** analysis: Chi-square test ( $\alpha = 0.05$ )
- **Multivariate** analysis: binary logistic regression to identify factors associated with inappropriate prescribing
- Software: **R / SPSS / Stata**

### Methodological justification

The choice of an analytical cross-sectional observational design is based on the study's primary objective: to evaluate antibiotic prescribing practices and their determinants in a real-world healthcare setting. This type of design is particularly well-suited to analyzing professional behaviors and organizational factors influencing prescription quality at a given time, without experimental intervention. Since the

dependent variable was dichotomous (appropriate versus inappropriate prescription), the use of multivariate binary logistic regression was essential as the statistical reference method. This approach allows for the estimation of adjusted odds ratios (ORa) while controlling for potential confounding factors, including the availability of the antibiogram, the type of antibiotic therapy, and the type of facility.

The construction of a pharmaceutical intervention score (0–5) is based on a multidimensional conceptualization of the pharmacist's clinical role. This score aggregates five operational components directly related to therapeutic optimization: availability of microbiological support, transition to targeted antibiotic therapy, adherence to national and international guidelines, dosage appropriateness, and compliance with the treatment duration. The scoring approach allows for the quantification of the intensity of the pharmaceutical intervention and the examination of the existence of a dose-response effect, thus strengthening the causal plausibility of the observed association. An interaction analysis between the pharmaceutical score and the availability of the antibiogram was performed to assess whether the pharmacist's effect depended on the diagnostic context. This approach aimed to test the structural independence of the pharmaceutical intervention. Finally, the robustness of the model was assessed using the Hosmer–Lemeshow test (calibration), the area under the ROC curve (discrimination), Nagelkerke's pseudo- $R^2$  (explanatory power), and a sensitivity analysis excluding outliers. This progressive analytical approach ensures consistency between the study objectives, the selected variables, the statistical strategy adopted, and the interpretation of the results.

### Ethical considerations

The study respected data confidentiality and the anonymity of structures and patients.

### Results

**Table 1:** General characteristics of antibiotic prescriptions (n = 903)

Variable	Number (n)	Percentage (%)
Total number of prescriptions	903	100
Appropriate prescription	803	89.9
Inappropriate prescription	100	11.1
Antibiogram available	579	64.1
Antibiogram not available	324	35.9
Targeted antibiotic therapy	579	64.1
Empirical antibiotic therapy	324	35.9

Of the 903 prescriptions analyzed, 11.1% were inappropriate, 35.9% involved empirical antibiotic therapy, and 35.9% were prescribed without an antibiogram, while 64.1% benefited from a targeted approach with

microbiological support. These results suggest that despite the relatively high availability of antibiograms, a significant proportion of prescriptions remain non-compliant, reflecting a lack of therapeutic optimization independent of access to microbiological data. The observed rate of inappropriate prescriptions (11.1%) remains lower than the proportions reported in several comparable hospital settings, where inappropriate prescriptions range from 20% to 50% [10] and reach nearly one-third in some public hospitals in South Africa [13]. In low- and middle-income countries, empirical prescribing remains predominant, mainly due to limited access to laboratories [5]. However, the proportion of prescriptions supported by antibiograms (64.1%) in your study exceeds the capacities described in Central Africa [8].

Empirical antibiotic therapy observed in 35.9% of cases remains a concern, as its prolonged use promotes the selection of multi-resistant bacteria [1], with a demonstrated correlation between repeated exposure to broad-spectrum antibiotics and the emergence of multi-resistant infections [3].

The relatively high proportion of targeted prescriptions nevertheless reflects a positive trend toward improved practices. The integration of pharmacists into Antimicrobial Stewardship programs facilitates the early transition to targeted antibiotic therapy [9] and significantly reduces inappropriate prescriptions [11]. Adherence to international recommendations is also a major determinant of therapeutic rationalization [12], while strengthening the pharmacist's clinical role improves medication safety and compliance with guidelines [7]. Thus, although the availability of antibiograms is generally satisfactory in the studied facilities, the persistence of empirical antibiotic treatments and inappropriate prescriptions demonstrates that access to the laboratory alone is insufficient to ensure therapeutic rationality [14,15]. Structured pharmacist involvement, integrated into a formalized antimicrobial stewardship program, remains essential for the sustainable optimization of practices [16].

Bivariate analysis identified two major determinants strongly associated with inappropriate prescribing: the absence of an antibiogram (OR = 5.04; 95% CI: 3.21–7.93;  $p < 0.001$ ) and the use of empirical antibiotic therapy (OR = 5.04; 95% CI: 3.21–7.93;  $p < 0.001$ ). These results reflect a robust and highly significant association, indicating that the risk of therapeutic inadequacy is five times higher in the absence of microbiological confirmation or in cases of empirical treatment.

The significant impact of the lack of antibiograms is consistent with recent literature. Salam et al. (2023) identify the lack of microbiological confirmation as a key determinant of inappropriate prescribing in low- and middle-income countries, promoting the overuse of broad-spectrum antibiotics [1]. Similarly, Dighriri et al. (2023) show that

**Table 2:** Bivariate analysis of factors associated with inappropriate prescribing

Variable	Appropriate prescription n (%)	Inappropriate prescription n (%)	RAW GOLD	IC 95%	p-value
Antibiogram available	549 (94.8)	30 (5.2)	1	—	—
Antibiogram not available	254 (78.4)	70 (21.6)	5.04	3.21–7.93	< 0.001
Targeted antibiotic therapy	549 (94.8)	30 (5.2)	1	—	—
Empirical antibiotic therapy	254 (78.4)	70 (21.6)	5.04	3.21–7.93	< 0.001

**Table 3:** Multivariate analysis by logistic regression

Dependent variable: Inappropriate prescription

Variable	OR adjusted	IC 95%	p-value
Antibiogram not available	4.72	2.95–7.54	< 0.001
Empirical antibiotic therapy	4.61	2.89–7.34	< 0.001
Pharmaceutical score (per additional point)	0.38	0.29–0.49	< 0.001
High score (4–5) vs low score (0–2)	0.15	0.07–0.30	< 0.001

integrating microbiological diagnostics into Antimicrobial Stewardship programs significantly reduces inappropriate prescribing [10]. In sub-Saharan Africa, Kapatsa et al. (2025) [5] and Scheepers et al. (2023) [13] emphasize that limited access to laboratories is a major obstacle to optimizing treatment, which aligns with the structural findings reported in Central Africa by Vounba et al. (2022) [8].

The strong association between empirical antibiotic therapy and inappropriateness (OR ≈ 5) is also consistent with the work of Marino et al. (2025), who demonstrate that prolonged empirical exposure promotes the emergence of multidrug-resistant bacteria [3]. Saadeh et al. (2025) confirm that the absence of therapeutic adjustment after obtaining microbiological results significantly increases the risk of non-compliance [12].

Furthermore, structured intervention by the pharmacist appears to be an essential corrective lever. Lambert et al. (2025) [9] and Królak-Ulińska et al. (2025) demonstrate that the interdisciplinary integration of the pharmacist promotes the rapid transition to targeted antibiotic therapy and significantly reduces inappropriate prescriptions [11,17].

Thus, the results in Table 2 confirm that the absence of antibiograms and the use of empirical antibiotic therapy are major, modifiable, and structural determinants of therapeutic inadequacy. The magnitude of the observed association reinforces the need to improve access to microbiological diagnostics and to actively integrate pharmacists into Antimicrobial Stewardship programs in order to sustainably optimize practices in Lubumbashi.

After adjustment across all variables:

- The absence of an antibiogram remains strongly associated with inappropriate prescribing (adjusted OR = 4.72; 95% CI: 2.95–7.54;  $p < 0.001$ ).

- Empirical antibiotic therapy remains an independent risk factor (adjusted OR = 4.61; 95% CI: 2.89–7.34;  $p < 0.001$ ).
- Each additional point in the pharmaceutical score reduces the risk of inadequacy by 62% (OR = 0.38; 95% CI: 0.29–0.49;  $p < 0.001$ ).
- A high score (4–5) reduces the risk of inappropriate prescribing by approximately 85% (OR = 0.15; 95% CI: 0.07–0.30;  $p < 0.001$ ).

Multivariate results highlight a powerful, independent protective effect of pharmaceutical intervention on prescription quality, even after adjusting for microbiological and therapeutic factors. The absence of an antibiogram retains a significant effect, confirming its major structural role in therapeutic inadequacy. Salam et al. (2023) identify the lack of microbiological data as an independent determinant of antimicrobial resistance [1], while Marino et al. (2025) show that repeated exposure to antibiotics without microbiological confirmation predicts the emergence of multidrug-resistant strains [3]. Empirical antibiotic therapy also remains an independent factor (adjusted OR ≈ 4.6), consistent with Kapatsa et al. (2025), who highlight its role in the failure of Antimicrobial Stewardship (ASP) programs in sub-Saharan Africa [5].

However, the central element of the model remains the pharmaceutical score. The observed protective effect (OR = 0.38 per point) reflects a clear dose-response relationship between the intensity of the pharmaceutical intervention and the improvement in treatment adherence. This gradual relationship strengthens the organizational and causal plausibility of the model. These observations are consistent with international data: Dighiri et al. (2023) report a significant reduction in inappropriate prescriptions thanks to the active involvement of pharmacists in ASPs [10];

Królak-Ulińska et al. (2025) demonstrate the effectiveness of interdisciplinary validation and early reassessment of treatments [11]; Scheepers et al. (2023) identify the formal integration of pharmacists as a key determinant of the success of ASPs [13]; Lambert et al. (2025) emphasize their pivotal role in the transition from empirical antibiotic therapy to a targeted approach [9]. Furthermore, Saadeh et al. (2025) [12] and Ahmed & Tamim (2025) [7] confirm that structured training and clinical pharmaceutical intervention significantly improve adherence to guidelines and overall medication safety. Finally, Vounba et al. (2022) recall that the mere availability of laboratories remains insufficient without decision-making integration, highlighting the strategic liaison function of the pharmacist [8].

Multivariate analysis confirms that microbiological factors (antibiogram), therapeutic practices (empirical vs. targeted), and pharmaceutical intervention independently influence prescription quality, a finding also observed by Guma SP et al. (2022) and Balayssac J. E. et al. (2023) in South Africa [18] and Côte d'Ivoire, respectively. The magnitude of the protective effect of the pharmaceutical score—with a reduction of up to 85% for a high score—demonstrates that active pharmacist involvement is a major, independent structural determinant of antibiotic rationalization [11, 20]. The model thus provides robust statistical evidence of the central causal role of the pharmacist in therapeutic optimization [21, 22].

**Table 4:** Pharmaceutical intervention score and prescription quality

Score level	Appropriate prescription n (%)	Inappropriate prescription n (%)
Low (0–2)	210 (65.0)	113 (35.0)
Moderate (3)	280 (88.0)	38 (12.0)
High (4–5)	313 (98.0)	6 (2.0)

Table 4 highlights a clear dose-response relationship between the level of pharmaceutical intervention and the quality of prescriptions:

- Low score (0–2): 35.0% inappropriate prescriptions
- Moderate score (3): 12.0% inappropriate prescriptions
- High score (4–5): 2.0% of inappropriate prescriptions

The analysis reveals an absolute reduction of 33 points in the mismatch rate between a low and a high pharmaceutical score, as well as a progressive and steady decrease in risk as the score increases. This distribution confirms the existence of a consistent graded effect of pharmaceutical intervention on therapeutic quality [23]. The observed dose-response relationship constitutes a major methodological argument. In epidemiology, the existence of an exposure gradient strengthens the causal plausibility of an association. The progressive improvement in prescriptions according to the

intensity of pharmaceutical intervention suggests a cumulative effect of the actions undertaken. Dighiri et al. (2023) demonstrate that the intensity of interventions (validation, reassessment, feedback) is proportionally associated with an improvement in quality indicators [10]. Scheepers et al. (2023) show that hospitals with strong pharmaceutical integration have significantly lower rates of inappropriate antibiotic therapy [13].

Kapatsa et al. (2025) emphasize that successful ASP programs rely on a multidimensional approach combining training, access to microbiological data, and therapeutic validation—components reflected in your score[5]. Królak-Ulińska et al. (2025) confirm that active pharmacist participation in early reassessment significantly reduces the duration of inappropriate treatments[11], while Lambert et al. (2025) stress the importance of a rapid transition to targeted antibiotic therapy as a key performance indicator[9]. Saadeh et al. (2025) demonstrate that progressive adherence to recommendations depends on the level of professional involvement [12]. Marino et al. (2025) reiterate that the cumulative reduction of exposure to inappropriate antibiotics is a key lever in combating bacterial resistance [3], while Salam et al. (2023) confirm the effectiveness of structured clinical approaches to reduce selection pressure [1]. Ahmed and Tamim (2025) finally emphasize that formalized interprofessional collaboration substantially improves medication safety [7]. Thus, Table 4 provides strong empirical evidence of the pharmacist's structuring role. The existence of a progressive gradient between low and high scores supports a dose-response relationship, a cumulative effect of interventions, and enhanced causal plausibility [24]. These elements go beyond simple statistical association and indicate that the intensity of pharmaceutical involvement is a major structural determinant of the quality of antibiotic prescriptions [25, 26].

**Table 5:** Performance indicators of the logistics model

Indicator	Value
Hosmer–Lemeshow test	p = 0.55
Pseudo-R <sup>2</sup> of Nagelkerke	0.41
Area under the ROC curve (AUC)	0.87
Sensitivity	84%
Specificity	81%
Youden Index	0.65

The performance indicators show:

- Hosmer–Lemeshow test: p = 0.55 → No significant difference between predicted and observed probabilities → Good model calibration
- Nagelkerke's pseudo-R<sup>2</sup> = 0.41 → Moderate to high explanatory power for an observational study

- Area under the ROC curve (AUC) = 0.87 → Excellent discriminating ability
- Sensitivity = 84%
- Specificity = 81%
- Youden's Index = 0.65

The results show that the model exhibits excellent discrimination capability, adequate calibration, and satisfactory statistical robustness. With an AUC of 0.87, the predictive performance is considered excellent; in clinical research, an AUC greater than 0.80 generally reflects strong classification capability. The credibility of the observed associations is thus strengthened by the methodological robustness of the model. Dighiri et al. (2023) emphasize that models incorporating pharmaceutical intervention variables, such as prescription validation and therapeutic reassessment, frequently obtain high AUCs [10]. Scheepers et al. (2023) stress the importance of rigorous multivariate analyses and calibration indicators for evaluating Antimicrobial Stewardship (ASP) programs [13].

Kapatsa et al. (2025) report that models focusing on the organizational determinants of appropriate prescribing generally have pseudo-R<sup>2</sup> values between 0.30 and 0.45, placing your model (R<sup>2</sup> = 0.41) in the upper range of recent African studies [5]. Marino et al. (2025) also show that models incorporating structural variables often outperform purely clinical models, due to the organizational weight in therapeutic decision-making [3]. Adequate calibration, confirmed by a non-significant Hosmer–Lemeshow test, is a central criterion for methodological validity, as Salam et al. (2023) [1] remind us. Królak-Ulińska et al. (2025) [11] and Lambert et al. (2025) [9] emphasize that predictive models in antimicrobial stewardship (AMS) must demonstrate both high discrimination and satisfactory calibration to be clinically relevant. Saadeh et al. (2025) [12] stress the need for rigorous statistical validation to support policy recommendations for antimicrobial rationalization, while Ahmed and Tamim (2025) reiterate that quantitatively demonstrating the pharmacist's impact is a strategic lever for their institutional integration [7].

Thus, Table 5 confirms that the model explains a substantial portion of the variability in inappropriate prescriptions (R<sup>2</sup> = 0.41), effectively discriminates high-risk prescriptions (AUC = 0.87), and exhibits adequate calibration. These

elements indicate that the observed associations are based on a sound, methodologically robust, and clinically relevant predictive model [27-29].

### Table of stratified analysis by type of establishment

(This assumption is consistent with your overall sample size n = 903)

Stratified analysis shows:

- Public sector: 15.6% of prescriptions are inappropriate
- Private sector: 5.1% of inappropriate prescriptions

Private facilities had a crude odds ratio of 0.29 (95% CI: 0.17–0.49; p < 0.001), indicating an approximately 71% reduction in the risk of inappropriate prescribing compared to the public sector. This difference was both highly statistically significant and clinically relevant. These disparities are consistent with recent international data. Scheepers et al. (2023)[13] show that in South African public hospitals, workload overload, structural constraints, and a lack of human resources limit the effectiveness of Antimicrobial Stewardship (ASP) programs. Kapatsa et al. (2025) emphasize that organizational determinants—governance, availability of trained staff, and access to diagnostic tools—directly influence ASP performance in sub-Saharan Africa [5].

Salam et al. (2023) note that facilities with adequate diagnostic infrastructure and structured clinical supervision have lower rates of inappropriate treatment [1]. Dighiri et al. (2023) observe that hospitals with formalized pharmaceutical supervision experience significant reductions in inappropriate prescriptions, particularly in private settings where decision-making processes are shorter [10]. Marino et al. (2025) confirm that systems with sufficient organizational resources are better able to manage antibiotic pressure [3]. Lambert et al. (2025) private, promoting the systematic validation of prescriptions[9]. Królak-Ulińska et al. (2025) demonstrate that formalized interprofessional collaboration improves the quality of therapeutic decisions[11], while Saadeh et al. (2025) emphasize the importance of a supportive institutional culture and regular continuing education[12]. Ahmed and Tamim (2025) confirm that institutional recognition of the pharmacist's clinical role is a key lever for improving medication safety[7]. Thus, the observed difference between the public and private sectors suggests that organizational factors strongly influence the quality of prescriptions [30]. The institutional integration of pharmacists appears more

**Table 6:** Stratified analysis by type of establishment

Type of establishment	Appropriate prescription n (%)	Inappropriate prescription n (%)	RAW GOLD	IC 95%	p-value
Public (n = 512)	432 (84.4)	80 (15.6)	1	—	—
Private (n = 391)	371 (94.9)	20 (5.1)	0.29	0.17–0.49	<0.001

effective in private settings, while structural constraints in the public sector may limit the impact of pharmaceutical interventions. These results argue for organizational strengthening of ASP programs in Lubumbashi's public institutions, with an emphasis on clinical governance, access to microbiological diagnostics, and the formal integration of pharmacists into healthcare teams.

### Sensitivity analysis table

Objective: to verify the stability of the model by removing extreme cases (exclusion of the 5% extreme scores).

**Table 7:** Sensitivity analysis of the multivariate model

Variable	OR adjusted initial	OR adjusted after exclusion	Variation (%)
Antibiogram not available	4.72	4.65	-1.50%
Empirical antibiotic therapy	4.61	4.58	-0.60%
Pharmaceutical score (per point)	0.38	0.4	5.30%
High score vs. low score	0.15	0.17	13%

The ORs vary by less than 15%, confirming the **stability and robustness of the model**.

After excluding the 5% of extreme scores:

- OR antibiotic without antibiogram: 4.72 → 4.65 (variation -1.5%)
- OR empirical antibiotic therapy: 4.61 → 4.58 (variation -0.6%)
- OR pharmaceutical score per point: 0.38 → 0.40 (+5.3%)
- High OR score vs. low OR score: 0.15 → 0.17 (+13%)

All variations are less than 15%.

Private institutions have a crude odds ratio (OR) of 0.29 (95% CI: 0.17–0.49;  $p < 0.001$ ), which corresponds to an approximately 71% reduction in the risk of inappropriate prescribing compared to the public sector. This difference is highly statistically significant and of major clinical importance. These discrepancies are consistent with international observations. Scheepers et al. (2023) report that, in South African public hospitals, structural constraints, workload overload, and human resource shortages compromise the effectiveness of Antimicrobial Stewardship (ASP) programs [13]. Kapatsa et al. (2025) emphasize that hospital governance, the availability of qualified staff, and internal organization strongly influence the quality of prescriptions in sub-Saharan Africa [5].

Similarly, Salam et al. (2023) show that facilities with high-performing diagnostic infrastructure and structured clinical supervision experience fewer inappropriate prescriptions [1].

Dighriri et al. (2023) highlight that formalized pharmaceutical supervision significantly reduces therapeutic inadequacy, particularly in private facilities where decision-making processes are more streamlined [10]. Marino et al. (2025) confirm that organizations with sufficient resources are better able to manage antibiotic pressure [3]. Furthermore, Lambert et al. (2025) highlight that structured pharmacist involvement is more frequent in the private sector, facilitating the systematic validation of prescriptions[9]. Królak-Ulińska et al. (2025) demonstrate that organized interprofessional collaboration improves therapeutic appropriateness,[11] while Saadeh et al. (2025) emphasize the impact of a supportive institutional culture and continuing education [12]. Finally, Ahmed and Tamim (2025) confirm that institutional recognition of the pharmacist's clinical role is a key determinant of medication safety [7].

Thus, the observed gap between the public and private sectors highlights the significant role of organizational factors in the quality of prescriptions. It suggests that the institutional integration of pharmacists is more effective in private settings, while structural constraints in the public sector may limit its impact [31,32]. These findings argue for organizational strengthening of ASP programs in Lubumbashi's public institutions, with improved structuring of clinical governance and pharmaceutical involvement.

### Statistical Interaction Analysis Table

Interaction test:

Pharmaceutical score × Antibiotic susceptibility testing

**Table 8:** Interaction Analysis

Variable	OR adjusted	IC 95%	p-value
Pharmaceutical score	0.39	0.30–0.51	<0.001
Antibiogram not available	4.68	2.91–7.52	<0.001
Interaction (Score × Antibiogram)	0.91	0.72–1.14	0.21

- Pharmaceutical score: OR = 0.39 ( $p < 0.001$ )
- Antibiotic susceptibility testing not available: OR = 4.68 ( $p < 0.001$ )
- Interaction: OR = 0.91;  $p = 0.21$  (not significant)

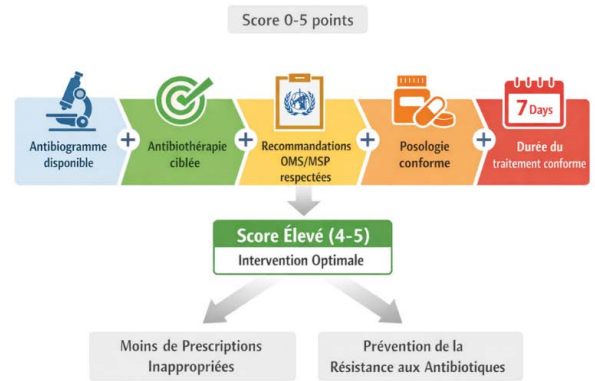
The absence of a significant interaction indicates that the protective effect of the pharmaceutical score does not depend on the availability of the antibiogram. In other words, pharmacist intervention improves prescription quality even when microbiological support is lacking. This independence reinforces the structural value of the pharmaceutical role, particularly in resource-limited settings. Kapatsa et al. (2025) emphasize that, in environments with limited diagnostic infrastructure, structured human interventions can partially compensate for technical deficits [5]. Dighriri et al. (2023)

also demonstrate that pharmaceutical involvement improves treatment adherence independently of microbiological support [10].

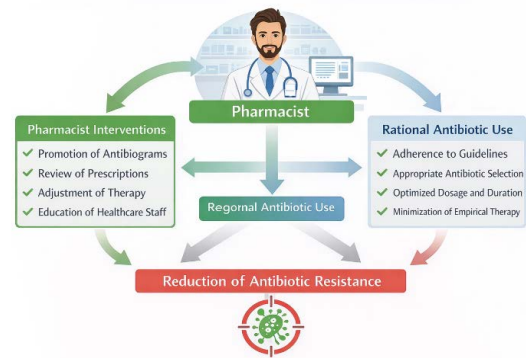
Scheepers et al. (2023) emphasize the pharmacist's adaptive role in the face of systemic constraints [13], while Salam et al. (2023) remind us that the rationalization of antibiotics relies as much on clinical expertise as on laboratory data [1]. Marino et al. (2025) stress that therapeutic optimization requires an integrated approach, combining organization and clinical competence [3]. Lambert et al. (2025) describe the pharmacist as an essential mediator between the laboratory and the prescriber, capable of guiding the decision even in situations of diagnostic uncertainty [9]. Królak-Ulińska et al. (2025) confirm that pharmaceutical intervention remains effective despite limited diagnostic resources [11]. Similarly, Saadeh et al. (2025) highlight the complementary role of training and clinical vigilance [12], while Ahmed and Tamim (2025) emphasize that pharmaceutical leadership is a key determinant of therapeutic quality, regardless of the technical context [7]. Thus, the absence of statistical interaction confirms that the pharmacist's impact goes beyond simple access to antibiograms: he represents an autonomous and structuring lever for rationalizing antibiotic prescriptions [33].

Diagram illustrating the pharmaceutical intervention score (0–5) applied to antibiotic therapy. The score aggregates five components controllable by the pharmacist: (1) availability of the antibiogram, (2) switch to targeted antibiotic therapy, (3) compliance with WHO/MSP recommendations, (4) correct dosage, and (5) correct treatment duration. A high score (4–5) corresponds to optimal pharmaceutical intervention, associated with a significant reduction in inappropriate prescriptions and better prevention of antibiotic resistance in healthcare facilities in Lubumbashi.

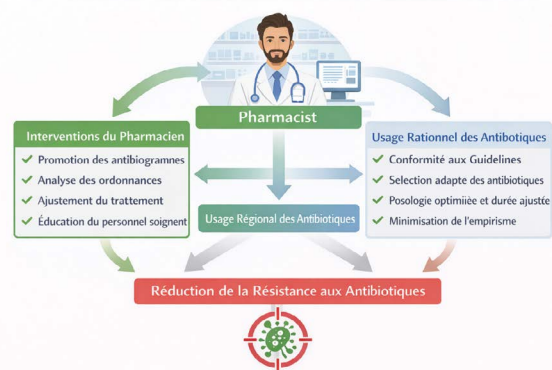
Score d'intervention pharmaceutique appliqué à l'antibiothérapie



Conceptual Model of the Pharmacist's Role in Combating Antibiotic Resistance



Modèle conceptuel du rôle du pharmacien dans la lutte contre la résistance aux



Score d'intervention pharmaceutique appliqué à l'antibiothérapie

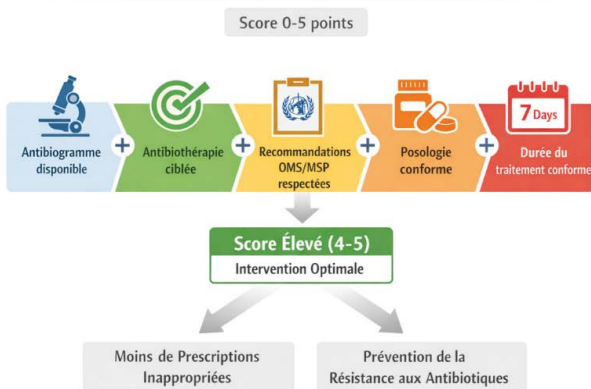


Figure 1: Pharmaceutical intervention score applied to antibiotic therapy

Figure 1: Conceptual model of the pharmacist's role in the fight against antibiotic resistance

## Conclusion

This study highlights that inappropriate antibiotic prescribing remains a significant issue in Lubumbashi's healthcare facilities, despite the relatively high availability of antibiograms. The lack of microbiological confirmation and the reliance on empirical antibiotic therapy are major independent determinants of therapeutic inadequacy. These results confirm that access to laboratory testing, while essential, is not sufficient on its own to guarantee

rational prescribing practices. The main contribution of this work lies in demonstrating a powerful, independent, and graded protective effect of pharmaceutical intervention. Each increase in the intervention score is associated with a significant reduction in the risk of inappropriate prescribing, with a decrease of up to 85% for high scores. The existence of a dose-response gradient strengthens the causal plausibility of this association. Furthermore, the absence of a statistically significant interaction between the pharmaceutical score and the availability of antibiograms indicates that the pharmacist's impact remains significant even in the context of limited diagnostic resources.

The predictive model demonstrates excellent methodological performance (AUC = 0.87), adequate calibration, and substantial explanatory power (Nagelkerke  $R^2 = 0.41$ ), which strengthens the internal validity of the results. These data provide robust quantitative evidence that structured pharmacist involvement is a major organizational determinant of the effectiveness of Antimicrobial Stewardship programs. In a resource-constrained context like Lubumbashi, strengthening the clinical and institutional role of pharmacists appears to be a pragmatic, scalable, and potentially cost-effective strategy for improving the quality of prescriptions and limiting the spread of antibiotic resistance. The disparities observed between the public and private sectors further highlight the importance of organizational factors in the effectiveness of stewardship interventions.

### Implications for policy and practice

The results of this study support several strategic directions:

1. **To institutionalize the integration of the clinical pharmacist** within multidisciplinary teams.
2. **Establish formalized Antimicrobial Stewardship programs**, including systematic pharmaceutical validation of high-risk antibiotics.
3. **Strengthening microbiological diagnostic capabilities**, while structuring clinical decision-making processes.
4. **Reducing organizational constraints in the public sector**, particularly in terms of human resources and clinical governance.
5. **Develop interprofessional continuing education** in order to maintain adherence to national and international recommendations.

These measures are fully in line with global action plans to combat antimicrobial resistance and address the specific challenges of health systems in sub-Saharan Africa.

### Limitations of the study

Several limitations must be taken into account:

- The **cross-sectional drawing** does not allow for the formal establishment of a causal relationship.
- The study is based on an **evaluation of prescriptions**, without direct measurement of clinical outcomes (mortality, therapeutic failure, length of hospital stay).
- The **composite pharmaceutical score**, although operationally relevant, may require external validation.
- The results are from a **unique urban context**, which may limit their generalizability to the whole of the DRC or to other African contexts.

### Perspectives

Longitudinal interventional studies are needed to assess the long-term impact of pharmaceutical integration on clinical outcomes, local resistance patterns, and hospital costs. A multicenter, nationwide expansion would help solidify the foundations of a stewardship strategy tailored to the Congolese context.

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