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Evaluation of Clinical Pharmacist Contributions within Infectious Disease Services: Classification, Acceptance Rate, and Economic Impact Assessment Using a Tailored Electronic Intervention Platform

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ABSTRACT

The presence of a specialized clinical pharmacist (CP) is vital for improving antimicrobial stewardship and optimizing therapeutic outcomes. This research aimed to analyze the spectrum of CP interventions in infectious disease (ID) management, emphasizing the nature of these interventions and their associated financial benefits through a tailored electronic documentation system. This retrospective observational study examined CP activities within the ID service of a tertiary hospital. The principal goal was to identify and categorize intervention types provided by CPs, while secondary goals included assessing physician acceptance levels and calculating cost reductions attributed to the electronic intervention tracking system. Across 187 patients managed by the ID consultation team, 464 pharmacist interventions were recorded. The most frequent types involved pharmacokinetic (PK) dosing and monitoring (25.9%) and renal dose optimization (20.7%). Collectively, these interventions resulted in an estimated cost reduction of about 234,666 Saudi Riyals (SAR), equivalent to roughly 62,577.60 United States Dollars (USD). The study underscores that CP engagement in ID services plays a key role in enhancing clinical efficiency, decreasing treatment costs, and shortening hospitalization periods.

Keywords: Interventions, Antimicrobial stewardship, Electronic intervention system, Cost saving, Infectious disease pharmacist

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Introduction

The growing threat of antimicrobial resistance, the rise in drug-related complications, and the increasing burden of healthcare expenditures have emphasized the urgent necessity to strengthen infectious disease (ID) management strategies. Antimicrobial resistance is now acknowledged as a critical global health challenge associated with significant mortality rates, demanding immediate and coordinated intervention [1]. If antimicrobial practices remain unoptimized, projections estimate that by 2050, resistance could account for nearly 10 million deaths annually worldwide (Global burden of bacterial antimicrobial resistance 2022). The inappropriate use of antimicrobials—including incorrect drug selection, dosage, route of administration, or treatment duration—continues to be a principal factor driving this crisis [2].

The inclusion of a dedicated clinical pharmacist (CP) with expertise in infectious diseases has become indispensable in promoting rational antimicrobial utilization and enhancing therapeutic efficacy. CPs are now integral members of multidisciplinary ID teams, where their targeted interventions improve treatment precision, minimize adverse outcomes, and contribute to cost efficiency. Their contributions play a vital role in mitigating antimicrobial resistance and optimizing patient outcomes [3, 4]. Numerous investigations have assessed the involvement of ID pharmacists and their clinical impact [5-8]. Nevertheless, data on the specific categories, acceptance rates, and economic implications of pharmacist-driven interventions in ID care remain scarce across various healthcare systems.

This retrospective analysis aimed to classify the intervention types conducted by CPs in infectious disease management and assess the corresponding physician acceptance rates and cost-saving outcomes. Estimating the financial impact of pharmacist activities is inherently complex, as it involves numerous clinical and institutional variables that are often underreported. When evaluating cost avoidance, it is necessary to account for both direct savings—such as substituting intravenous (IV) therapy with oral (PO) formulations—and indirect savings, such as reducing hospital stays through initiatives like transitioning patients to home-based elastomeric infusion pumps for IV antimicrobial therapy.

Despite the relevance of such assessments, few studies have explored electronic systems that quantify CP interventions and translate them into measurable cost benefits tailored to institutional parameters. The present study aimed to assess the nature and outcomes of interventions implemented by an infectious disease–trained CP using a customized electronic reporting tool. The system employed—Quantifi by Wolters Kluwer—facilitates documentation of pharmacist activities and calculates cost savings through validated cost avoidance models. These models are adapted to institutional data on hospitalization costs, laboratory investigations, diagnostic procedures, and formulary medication prices, enabling a precise and localized economic analysis.

Materials and Methods

Study design and setting

This retrospective observational study examined interventions made by clinical pharmacists within the ID service of a tertiary academic hospital housing over 500 beds. Data were retrieved from the Quantifi (Wolters Kluwer) electronic documentation platform and patient electronic health records over a nine-month period, from January 2022 to September 2022.

Study population

Eligible participants included adult patients (≥18 years old) who received care under the ID service and had at least one intervention documented by an ID-specialized clinical pharmacist. The recorded interventions comprised actions such as correction of antimicrobial bug/drug mismatches, de-escalation or optimization of antimicrobial therapy, discontinuation according to recommended duration, IV-to-PO conversion, enrollment in home-based elastomeric pump therapy, pharmacokinetic (PK) dosing and monitoring, and renal dosing adjustments.

Definitions of intervention types

Antimicrobial bug/drug mismatch refers to cases in which the prescribed antibiotic fails to target the organism identified in culture results [9].

Antimicrobial de-escalation involves discontinuing one or more empirically used broad-spectrum agents or substituting them with narrower-spectrum alternatives once culture results become available [10].

Optimization of antimicrobial therapy includes individualizing dosing strategies based on patient-specific factors—such as age, weight, and renal or hepatic function—alongside pharmacokinetic and pharmacodynamic parameters and pathogen characteristics [11, 12].

IV-to-PO switch denotes the replacement of an intravenous medication with its oral equivalent or a different oral agent of similar efficacy, even if dosing frequency, strength, or antimicrobial spectrum differ [13].

Patient enrollment on an elastomeric pump applies to individuals requiring prolonged IV antimicrobial therapy who cannot be transitioned to oral medication due to the infection site or resistance profile. Such patients may continue therapy at home once clinically stable, using an elastomeric pump. For instance, patients with complicated urinary tract infections caused by extended-spectrum β-lactamase (ESBL)–producing bacteria and requiring IV ertapenem can be discharged under this program. The process includes screening for eligibility, patient counseling, obtaining consent, and monitoring until treatment completion.

Pharmacokinetic (PK) dosing and monitoring entail customizing antimicrobial doses to achieve optimal therapeutic exposure while minimizing toxicity and the risk of resistance development [14]. This approach is applied to agents requiring serum concentration monitoring, including vancomycin, aminoglycosides, and voriconazole.

Outcome measures

The principal aim of this study was to classify and analyze the various types of clinical pharmacist interventions implemented within infectious disease (ID) services during the study period. Secondary objectives included assessing the rate of physician acceptance of these interventions, estimating cost savings generated from accepted pharmacist recommendations using the electronic intervention tracking system, and identifying intervention categories associated with the most substantial financial impact.

Cost savings

Cost savings were estimated through two categories: hard costs, representing measurable monetary savings in Saudi Riyals (SAR) and U.S. Dollars (USD) achieved through drug substitutions or changes in administration routes; and soft costs, which correspond to the financial value of interventions that prevent additional hospitalization days. The assigned value for each intervention type was based on evidence from multiple published studies, adjusted to reflect our institution's specific parameters, including hospital bed-day costs, local medication prices, laboratory test fees, and the average time required for each intervention.

To construct institution-specific cost-saving calculations, the Pharmacy OneSource software was employed. This system incorporated our hospital's formulary data and utilized validated cost avoidance formulas to estimate economic benefit.

For instance, in the case of a therapeutic interchange, the formula calculates the average cost difference between commonly substituted antimicrobials and multiplies it by the "days of therapy impacted" to determine the intervention's overall value. Similarly, for pharmacokinetic (PK) interventions, cost avoidance reflects the average expense of the avoided serum drug level tests at our facility.

For IV-to-PO conversions, the system computes the mean cost differential between equivalent intravenous and oral formulations and multiplies that by the estimated number of therapy days influenced. As an illustration, one day of IV Bactrim therapy costs approximately 21 SAR (≈5.6 USD), compared to 4 SAR (≈1.1 USD) for the oral formulation—a difference of 17 SAR per day, which is then multiplied by the duration of therapy modified through the intervention.

Cost analysis and system customization

At our institution, the Quantifi system was customized to mirror actual local cost structures. Drug cost-saving formulas were tailored using procurement data from the hospital pharmacy, while hospitalization-related expenses were calibrated according to finance department estimates for average bed-day costs in both general wards and intensive care units. Likewise, laboratory and diagnostic test cost reductions were determined using figures supplied by the laboratory department. Although these values were institution-specific, the Quantifi framework is adaptable and can be modified to suit financial parameters from other healthcare facilities, allowing broad applicability across different systems once local data are integrated.

Data collection

Throughout the nine-month study period, all ID pharmacist interventions were documented in the Quantifi system (Wolters Kluwer). The data captured included patient identifiers, consulting service, implicated antimicrobials, intervention type, physician acceptance, and therapy duration impacted. Each intervention was automatically translated by the system into a cost-saving figure using validated formulas and institutional cost metrics. The configuration and validation of the system were collaboratively executed by two clinical pharmacists, a drug information specialist, and an IT pharmacist to ensure precision, reliability, and accuracy. Moreover, every recorded intervention was reviewed by an independent clinical pharmacist and a medication safety pharmacist for quality assurance.

Ethical approval

The study protocol received ethical clearance from the Institutional Review Board (IRB) at Imam Abdulrahman bin Faisal University (Approval No. IRB-2025–05–0406).

Statistical analysis

Data analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 25 (IBM Corp., Armonk, NY, USA). Descriptive statistics were applied to summarize the findings: frequencies and percentages for categorical variables, and means with standard deviations for continuous variables. Associations between

intervention types and outcomes were evaluated using the Chi-square test, with a p-value ≤ 0.05 considered statistically significant.

Results and Discussion

A total of 693 interventions were retrieved from the electronic documentation system. After excluding 229 interventions involving patients younger than 18 years or those conducted outside the ID service, 464 interventions performed on 187 patients managed under the ID consultation service were analyzed. The mean patient age was 64.2 ± 16.5 years. The distribution of infection types among these patients included urinary tract infections (27.8%), respiratory tract infections (27.3%), skin and soft tissue infections (17.6%), bone and joint infections (6.4%), and other infections—such as intra-abdominal, line-related, and central nervous system infections—accounting for 20.9% of the cases.

Table 1. Patient baseline characteristics, infection types, and renal function

Characteristics	Values
Age (mean ± SD, years)	64.2 ± 16.5
Gender	
Male	79 (42.2%)
Female	108 (57.8%)
Type of infection	
Urinary tract infection	52 (27.8%)
Respiratory tract infection	51 (27.3%)
Skin and soft tissue infection	33 (17.6%)
Bone and joint infection	12 (6.4%)
Other infections	39 (20.9%)
Baseline renal function (median, IQR)	
Serum creatinine (mg/dL)	1.3 (0.6–2.4)
Creatinine clearance (mL/min)	44 (26–98)

SD, standard deviation; IQR, interquartile range.

As shown in **Table 2**, the interventions most frequently performed by the ID pharmacist were pharmacokinetic (PK) dosing and monitoring (25.9%), renal dose adjustment (20.7%), and antimicrobial de-escalation (14%).

Table 2. Types, numbers, and cost savings of ID pharmacist interventions.

Intervention type	Number of interventions	Percentage (%)	Cost savings in SAR	Cost savings in USD
Bug/Drug Mismatch	40	8.6	9960	2656.00
Antimicrobial De-escalation	65	14	12940	3450.67
Antimicrobial optimization	48	10.3	8466	2257.60
Discontinuation Of Drug Therapy	39	8.4	5850	1560.00
IV-to-PO switch	27	5.8	3250	866.67
Patient Enrolment on OPAT	29	6.3	151960	40522.67
PK Dosing/Monitoring	120	25.9	28800	7680.00
Renal Dosing	96	20.7	13440	3584.00
Total	464		234,666	62577.60

IV, intravenous; OPAT, outpatient parenteral antimicrobial therapy; PK, pharmacokinetics; PO, by mouth; SAR, Saudi Riyal; USD, United States dollar

Additional interventions carried out by the ID pharmacist included antimicrobial optimization (10.3%), correction of antimicrobial bug/drug mismatches (8.6%), discontinuation of therapy (8.4%), patient enrollment in home-based elastomeric pump programs (6.3%), and intravenous-to-oral (IV-to-PO) conversions (5.8%). Within the

pharmacokinetic (PK) dosing and monitoring category, vancomycin accounted for the majority of cases (79%), followed by gentamicin (21%). **Table 3** presents the distribution and percentage of pharmacist interventions by antimicrobial agent. The medications most frequently associated with pharmacist interventions **(Figure 1)** were meropenem (18%), piperacillin/tazobactam (15%), vancomycin (11%), colistin (10%), and cefepime (5%).

Table 3. Clinical pharmacist intervention frequencies to optimize antimicrobial management per antimicrobial.

Antimicrobial	Clinical pharmacist interventions	
	Number	(%)
Meropenem	83	18.0%
Piperacillin/Tazobactam	70	15.0%
Vancomycin	46	10.0%
Colistin	46	10.0%
Cefepime	23	5.0%
Ceftazidime/Avibactam	19	4.0%
Ertapenem	19	4.0%
Gentamicin	19	4.0%
Ciprofloxacin	19	4.0%
Ceftazidime	14	3.0%
Clindamycin	14	3.0%
Acyclovir	9	2.0%
Amoxicillin/Clavulanate	9	2.0%
Amphotericin B	9	2.0%
Caspofungin	9	2.0%
Linezolid	9	2.0%
Cefazolin	9	2.0%
Amikacin	9	2.0%
Trimethoprim-sulfamethoxazole	9	2.0%
Anidulafungin	5	1.0%
Voriconazole	5	1.0%
Azithromycin	5	1.0%
Fluconazole	5	1.0%

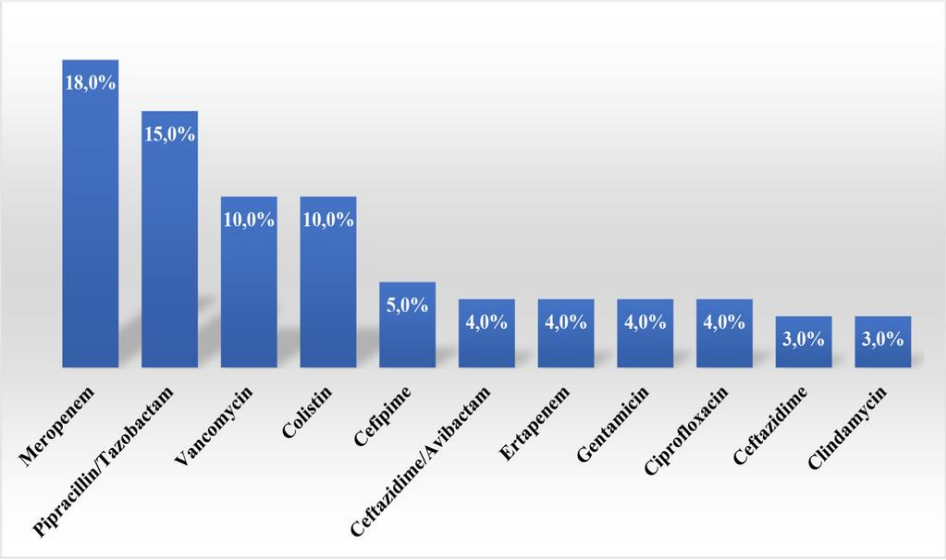

Figure 1. Antimicrobial agents most frequently associated with interventions performed by the infectious disease clinical pharmacist.

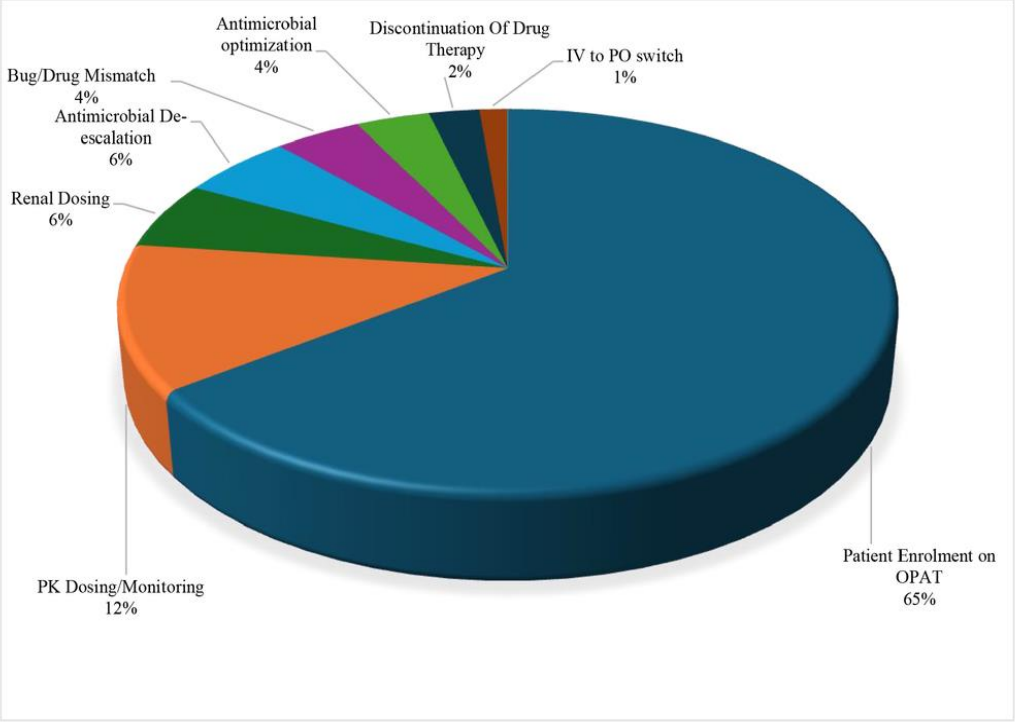

Figure 2. The percentage of cost reduction associated with each intervention performed by the infectious disease clinical pharmacist.

For patients enrolled in home-based elastomeric pump therapy, ertapenem was the most frequently utilized antimicrobial (87%). The IV-to-PO conversion interventions were most commonly applied to ciprofloxacin (22%) and clindamycin (18%). The overall acceptance rate of interventions by the infectious disease (ID) team reached 96%.

Among the 464 interventions, the total cost savings estimated through the customized electronic system amounted to 234,666 Saudi Riyals (SAR) (approximately 62,577.6 USD). The greatest financial impact was observed in patient enrollment on elastomeric pumps, accounting for 151,960 SAR (≈40,522.7 USD) in savings, followed by pharmacokinetic (PK) dosing/monitoring interventions (28,800 SAR / 7,680 USD) and renal dose adjustments (13,440 SAR / 3,584 USD).

Furthermore, patients managed under the ID clinical pharmacist's supervision were significantly more likely to experience shorter hospital stays (<10 days) compared with those who were not reviewed (106 of 187 [57%] vs. 19 of 50 [38%]; p = 0.025) **(Table 4)**.

Table 4. Length of hospital stay of patients reviewed vs. not reviewed by the ID clinical pharmacist.

Length of hospital stay (Days)	Patients not reviewed by an ID clinical pharmacist*	Patients under ID clinical pharmacist review	P-value
<10 days	19 (38%)	106 (57%)	0.0187
≥ 10 days	31 (62%)	81(43%)	

* During the clinical pharmacist's leave.

This study underscored the indispensable contribution of infectious disease (ID) clinical pharmacists as integral members of the multidisciplinary ID care team. The pharmacists carried out a wide spectrum of interventions, most frequently related to pharmacokinetic (PK) dosing and monitoring (25.9%), renal dose adjustment (20.7%), and antimicrobial de-escalation (14%). Collectively, these activities yielded an estimated cost savings of 234,666 SAR (approximately 62,577.6 USD) during the study period. Among all interventions, patient enrollment on elastomeric pumps generated the greatest cost reduction, followed by PK dosing/monitoring and renal dosing. The adaptation of a customized electronic intervention system—incorporating cost-saving formulas derived from institutional data—proved valuable for systematic documentation, tracking, and quantification of cost savings.

The notably high physician acceptance rate of 96% reflects strong interprofessional collaboration and acknowledgment of pharmacists' clinical impact within the healthcare team.

While numerous studies have investigated the involvement of pharmacists in ID services and categorized the types of interventions performed, few have developed methods to quantify the financial benefits associated with these interventions. For instance, Salman *et al*. (2015) conducted a study in a 500-bed teaching hospital in Oman that assessed both the clinical and financial implications of pharmacist-led antimicrobial interventions. Dosing adjustments constituted the most prevalent intervention (42%), followed by antimicrobial discontinuation (34%), paralleling our findings where PK dosing and monitoring were predominant (25.9%). That study estimated an annual cost savings of roughly 200.2 million USD based on a predefined cost avoidance model combined with direct cost reduction. However, their methodology did not include an electronic tool for standardized calculation or reporting of cost reductions, nor did it assess physician acceptance rates.

Similarly, Leache *et al*. (2020) [15] examined the clinical and economic influence of pharmacist interventions targeting antimicrobial therapy among critically ill ICU patients. Their retrospective analysis, spanning five months, identified 212 drug-related issues across 114 patients, including 18 medication errors. The resulting cost reduction amounted to 10,905 euros (approximately 12,453.5 USD), with an impressive physician acceptance rate of 97.6%, aligning closely with the 96% rate observed in our study.

In another investigation, Ali Hassan *et al*. (2021) evaluated the impact of clinical pharmacy and antimicrobial stewardship initiatives for ID patients in a tertiary hospital in Lahore using a before-and-after design. The authors reported 136 interventions, 66% of which were accepted by physicians, lower than in our findings. Nonetheless, their most frequent activities, such as spectrum-based antibiotic selection and dose de-escalation, corresponded with our results, where antimicrobial de-escalation accounted for 14% and antimicrobial optimization for 10.3% of total interventions.

Furthermore, a five-year study from Amui Hospital in China assessed ID pharmacist participation in antimicrobial stewardship efforts and demonstrated a considerable cost avoidance of 7.63 million USD. However, their cost analysis was confined to reductions in hospital length of stay, unlike our approach, which incorporated both tangible and intangible cost elements, providing a more comprehensive evaluation of pharmacist-driven economic impact.

Our findings indicate that the involvement of an ID clinical pharmacist is linked to a significantly reduced hospital length of stay, with patients receiving pharmacist review being more likely to be discharged within 10 days compared to those without such review (57% vs. 38%, $p = 0.0187$). A key factor contributing to shorter stays was the pharmacist's role in managing elastomeric home infusion pumps, which allow patients to continue therapy at home while requiring structured patient and caregiver education, daily monitoring, and weekly laboratory follow-up—all coordinated by the ID pharmacist. These results align with prior research highlighting that ID pharmacist interventions are widely accepted and produce tangible economic benefits. However, previous studies did not examine the development of a customizable electronic platform that translates interventions into cost savings, incorporating both direct and indirect costs. Implementing such a system not only standardizes and streamlines interventions but also saves time and ensures consistent reporting.

Traditional approaches, such as chart reviews with paper-based documentation, are labor-intensive, prone to reporting bias, and limited in capturing real-time data. In contrast, the electronic Quantifi system allowed prospective, standardized documentation of interventions, facilitated cost analysis, and enabled consistent categorization across clinical scenarios. Nevertheless, unlike multicenter databases or validated scoring tools, Quantifi is largely institution-specific, requiring customized cost parameters, which improves internal accuracy but limits cross-institutional comparability. Future studies should evaluate Quantifi or similar platforms against established scoring systems to define their relative strengths, limitations, and potential for broader implementation in diverse healthcare settings.

This study has several limitations, including its retrospective design, single-center setting, and focus on a specific ID subspecialty, which may restrict the generalizability of results. The sample size was relatively small, and the study period coincided with the COVID-19 pandemic, which could have influenced clinical practices, infection control measures, and antimicrobial use patterns. Additionally, while we assessed the length of hospital stay, other critical outcomes—such as mortality, morbidity, readmissions, and adverse drug events—were not analyzed due to data constraints. Future research involving larger, more diverse patient populations will provide a more comprehensive understanding of the impact of ID pharmacist interventions.

Conclusion

This study underscores the importance of integrating ID clinical pharmacists into ID services to enhance patient outcomes and promote cost efficiency. Systematic documentation and promotion of their interventions are essential for reinforcing their role as key members of the healthcare team in tackling antimicrobial resistance and improving healthcare quality. Customizing electronic systems to institutional needs further supports these objectives by enabling standardized reporting, real-time data capture, and measurable economic evaluation.

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