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Clinical Pharmacy

for Pharmacy Students

Lesson 11:

Antibiotic Stewardship in Clinical Pharmacy

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Lesson 11: Antibiotic Stewardship in Clinical Pharmacy

Contents

11.1 Antimicrobial Stewardship and Infection Control

Antimicrobial stewardship and **infection control** represent two interdependent pillars of contemporary clinical pharmacy practice in infectious diseases. Together, they aim to optimize antimicrobial therapy for individual patients, reduce the incidence of infections (particularly healthcare-associated infections), and slow the emergence and spread of antimicrobial resistance, while maintaining a strong focus on patient-centered outcomes such as cure, avoidance of treatment-related harm, and preservation of future therapeutic options.

Antimicrobial stewardship, as framed in major reviews and guidance documents, encompasses a **coordinated set of interventions designed to promote the selection of the optimal antimicrobial regimen, including drug, dose, route, and duration, for the prevention and treatment of infections**. The goal is not to simply reduce antimicrobial use, but to ensure that therapy is appropriate, timely, and no broader or longer than necessary, to maximize clinical effectiveness and minimize adverse effects. **Infection prevention and control** complements stewardship by **focusing on measures that prevent acquisition and transmission of pathogens in healthcare and community settings**, such as hand hygiene, isolation precautions, device-care bundles, environmental hygiene, and vaccination. Effective infection prevention reduces the need for systemic antimicrobials in the first place and thereby supports the objectives of stewardship.[1]

Clinical pharmacy in infectious diseases can be viewed as operating on two interconnected levels. **At the bedside**, the clinical pharmacist contributes directly to patient care through activities such as participating in multidisciplinary ward rounds, reviewing antimicrobial prescriptions, advising on empirical and targeted therapy, adjusting doses for organ dysfunction

[1] Ntim OK, Opoku-Asare B, Donkor ES. A systematic review of antimicrobial stewardship interventions implemented in intensive care units. J Hosp Infect. 2025;162:272-283.

and pharmacokinetic variability, monitoring for adverse effects and interactions, and educating patients and caregivers about antimicrobial use and infection-prevention behaviors. **At the organizational and policy level**, pharmacists are involved in developing and updating local antimicrobial guidelines and pathways, constructing and interpreting antibiograms, designing and implementing stewardship interventions, contributing to infection-control policies (for example around surgical prophylaxis or device management), and monitoring quality indicators and utilization data to inform continuous improvement.

11.1.1 Burden of Antimicrobial Resistance and Healthcare-Associated Infections

Antimicrobial resistance and healthcare-associated infections together represent one of the most important threats to the effectiveness of anti-infective therapy and to the quality and safety of healthcare. **Antimicrobial resistance** is now estimated to be directly responsible for more than one million deaths annually worldwide and to be associated with several million additional deaths, with substantial variation between regions and a disproportionate impact on low- and middle-income countries.[2] In parallel, **healthcare-associated infections** remain among the most frequent adverse outcomes of hospital care, occurring in a significant proportion of admitted patients and contributing to excess morbidity, mortality, and resource use across diverse health systems.

From a hospital perspective, both antimicrobial resistance and healthcare-associated infections have well-documented consequences for length of stay, mortality, and costs. Studies show that infections caused by resistant organisms are associated with longer hospitalization (often an excess of about one week on average), higher odds of in-hospital death, and increased risk of readmission when compared with otherwise similar infections due to susceptible pathogens. Healthcare-associated infections such as central line-associated bloodstream infection, ventilator-associated pneumonia, and catheter-associated urinary tract infection similarly prolong hospital stay, increase mortality, impair quality of life, and increase direct healthcare expenditure, with intensive care units and other high-risk environments bearing a particularly heavy burden. At national and global levels, modelling studies indicate that the direct inpatient costs of antimicrobial resistance alone amount to tens of billions of US dollars per year, with indirect costs related to productivity losses and long-term disability adding substantially to this figure and again falling most heavily on health systems with constrained resources.[3]

There are also marked regional and global differences in the patterns and consequences of antimicrobial resistance and healthcare-associated infections, which shape priorities for stewardship and infection prevention. In some regions, for example, carbapenem-resistant Enterobacterales, extensively drug-resistant Acinetobacter, and high rates of methicillin-resistant Staphylococcus aureus dominate the resistance landscape, whereas in others extended-spectrum beta-lactamase-producing Enterobacterales or fluoroquinolone-resistant organisms are more prominent. The incidence and impact of

[2] Antimicrobial Resistance Collaborators. Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. Lancet. 2022;399(10325):629-655.
[3] Naylor NR, Hasso-Agopsowicz M, Kim C, et al. The global economic burden of antibiotic-resistant infections and the potential impact of bacterial vaccines: a modelling study. BMJ Glob Health. 2025;10(6):e016249.

healthcare-associated infections also vary between countries and even between hospitals, influenced by case mix[4], device use, staffing levels, and adherence to prevention bundles[5].

11.1.2 Organization of Stewardship and Infection Control Programs

Antimicrobial stewardship and infection prevention programs are most effective when they are embedded in formal institutional structures with defined leadership, clear accountability, and multidisciplinary participation spanning both hospital and ambulatory care. Over the past decade, regulatory agencies, professional societies, and accreditation bodies have converged on a set of core elements that describe how these programs should be organized and governed, while allowing local adaptation to resources and epidemiology. [6]

Core Elements and Governance in Hospitals

Widely cited frameworks, such as the CDC Core Elements for Hospital Antibiotic Stewardship and the SHEA/IDSA[7] guideline on implementing ASPs, emphasize eight interrelated components: institutional leadership commitment, accountability, drug expertise, action, tracking, reporting, education, and, more recently in some adaptations, integration with infection prevention and diagnostic stewardship. These elements provide a pragmatic template for hospitals to develop stewardship capacity regardless of size, with larger centers adding more specialized structures and smaller hospitals meeting the same functions with fewer individuals carrying multiple roles.

Institutional leadership commitment usually takes the form of written support for the antimicrobial stewardship program, inclusion of stewardship in strategic plans, allocation of protected time and budget for key personnel, and linkage of stewardship program indicators to organizational quality and safety dashboards. Accountability is commonly operationalized through the designation of a program leader, often an infectious diseases physician, and a co-lead with expertise in antimicrobial pharmacotherapy, typically a clinical pharmacist with infectious diseases training.

The multidisciplinary stewardship team is a defining organizational feature. Core membership usually includes at least one infectious diseases physician, a clinical pharmacist, a clinical microbiologist, an infection prevention practitioner, and a representative from nursing, with additional participation from hospital epidemiology, information technology, and hospital administration. The team is responsible for developing and updating institutional guidelines and pathways, prioritizing and implementing stewardship interventions (for example, prospective audit and feedback, pre-authorization, intravenous-to-oral switch policies, and optimization of surgical prophylaxis), and monitoring key metrics such as antibiotic consumption,

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[4] **Case mix** refers to the composition of a healthcare provider's patient population in terms of the types of conditions treated, their severity, and associated comorbidities, which together determine the expected resource needs and outcomes for that setting.

[5] **Prevention bundles** are small, clearly defined sets of evidence-based measures that are implemented together for a specific clinical situation to improve reliability of care processes and reduce infection risk in a way that has greater impact than single, isolated interventions.

[6] Pollack LA, Srinivasan A. Core elements of hospital antibiotic stewardship programs from the Centers for Disease Control and Prevention. Clin Infect Dis. 2014;59 Suppl 3(Suppl 3):S97-S100.

[7] IDSA: Infectious Diseases Society of America; and SHEA: Society for Healthcare Epidemiology of America.

appropriateness of prescribing, rates of Clostridioides difficile infection, and selected resistance patterns.

PPCIRA (Programa de Prevenção e Controlo de Infeções e de Resistência aos Antimicrobianos)

The PPCIRA is the national program of the Portuguese Ministry of Health for the prevention and control of healthcare-associated infections and antimicrobial resistance. It was created in 2013 as a priority program of the Direção-Geral da Saúde (DGS) with the explicit **aim of reducing the incidence of healthcare-associated infections, promoting appropriate and responsible antimicrobial use, and decreasing the prevalence of microorganisms with acquired resistance in Portugal**.

At the national level, PPCIRA defines strategic objectives, issues technical guidance and normative documents, coordinates surveillance systems for healthcare-associated infections, antimicrobial consumption and resistance, and manages the **PPCIRA Quality Index**, a composite indicator used in contracting and performance assessment of SNS institutions.

At institutional level, **each ULS must maintain a ULS-PPCIRA as an organic unit of the organization, with its own leadership and dedicated staff time**, in line with the requirements set out in Despacho n.º 10901/2022. Hospital UL-PPCIRA units are required to have a medical director and a nurse manager with full-time dedication to the program, and to be multidisciplinary in composition, explicitly including physicians, nurses, pharmacists, and other health professionals, as well as at least one member with competence in quality and implementation science. Their mandate covers promotion and supervision of infection-prevention practices, management and surveillance of antimicrobial consumption and resistance, participation in national epidemiological surveillance networks, internal clinical audit, and local education for professionals. The director of the hospital ULS-PPCIRA must sit on the institutional quality and safety committee and on the pharmacy and therapeutics committee, which provides a formal link between PPCIRA, antimicrobial stewardship, and broader governance of medicines and patient safety.

A key feature of PPCIRA is the explicit integration of antimicrobial stewardship into infection prevention structures. National legislation requires local PPCIRA units to implement formal antibiotic stewardship programs (**Programas de Gestão do Uso de Antibióticos**) aimed at optimizing antimicrobial therapy and reducing ecological impact, making stewardship a contractual obligation for hospitals within the SNS. PPCIRA also defines a set of indicators that are incorporated into the contracting process and used to benchmark institutions.

Organization in ambulatory and community settings

In ambulatory care, stewardship and infection prevention are organized differently, reflecting the distributed nature of prescribers and the absence of a single physical institution. The CDC Core Elements for Outpatient Antibiotic Stewardship describe four key domains (i.e., commitment, action for policy and practice, tracking and reporting, and education and expertise) that mirror

the hospital framework but are adapted to primary care clinics, urgent care centers, emergency departments, and other ambulatory settings.[8]

Because ambulatory stewardship often lacks dedicated infectious diseases staff, program organization relies heavily on clinical pharmacists when available, on medical directors or lead general practitioners, and on centralized support from health systems, or public health agencies. In integrated delivery systems, ambulatory stewardship and infection prevention are frequently overseen by the same governance structures as hospital programs, with shared guidelines, and common performance indicators, whereas in smaller or independent practices these functions may be coordinated regionally by public health bodies or professional organizations. Infection prevention in ambulatory care is usually embedded in occupational health and practice management policies (for example, vaccination of staff, respiratory hygiene and mask use during viral seasons, and safe injection practices) but increasingly interfaces with stewardship through initiatives to reduce unnecessary antibiotic prescribing for acute respiratory infections.[9]

Clinical Pharmacists in Stewardship Teams

Clinical pharmacists should occupy a relevant position in both hospital and ambulatory stewardship organizations because of their expertise in antimicrobial pharmacology, dosing, drug–drug interactions, and formulary management. In many ASPs, a clinical pharmacist with infectious diseases training is designated as the co-leader or operational lead of the program, responsible for day-to-day stewardship activities, coordination of interventions, and liaison with frontline clinical teams. Pharmacist-led interventions, such as prospective audit and feedback, dosage optimization in renal or hepatic impairment, therapeutic drug monitoring for agents with narrow therapeutic indices, and structured IV-to-oral switch programs, are among the most consistently reported components of effective ASPs and are key determinants of the program's visibility to prescribers.[10]

To perform these functions, clinical pharmacists in stewardship roles require a defined set of competencies that extend beyond general clinical pharmacy skills. Competency frameworks and regional experience consistently highlight the need for advanced knowledge of infectious diseases, antimicrobial pharmacokinetics and pharmacodynamics, microbiology, and principles of infection prevention and control. Pharmacists should be able to interpret culture and susceptibility results, understand local epidemiology and resistance mechanisms, and integrate this information into patient-level and policy-level recommendations, including the design of empiric and targeted therapy regimens and de-escalation strategies.

Stewardship pharmacists should also be familiar with basic epidemiological and quality-improvement methods, including the design of audits and feedback cycles, use of process and outcome indicators, and interpretation of utilization data, enabling them to participate in or lead stewardship projects and to evaluate their impact on prescribing behavior and clinical outcomes. Formal training pathways, such as postgraduate residencies or master's programs in infectious diseases pharmacy, and ongoing continuing professional development in

[8] Keller SC, Cosgrove SE, Miller MA, Tamma P. A framework for implementing antibiotic stewardship in ambulatory care: Lessons learned from the Agency for Healthcare Research and Quality Safety Program for Improving Antibiotic Use. Antimicrob Steward Healthc Epidemiol. 2022;2(1):e109.
[9] Eudy JL, Pallotta AM, Neuner EA, et al. Antimicrobial Stewardship Practice in the Ambulatory Setting From a National Cohort. Open Forum Infect Dis. 2020;7(11):ofaa513.
[10] Jantarathaneewat K, Camins B, Apisarnthanarak A. The role of the clinical pharmacist in antimicrobial stewardship in Asia: A review. Antimicrob Steward Healthc Epidemiol. 2022;2(1):e176.

stewardship and infection prevention are increasingly recommended to support these competencies.

11.2 Core Bedside Antimicrobial Optimization Activities

Bedside antimicrobial optimization starts at the moment infection is suspected and continues throughout the course of therapy, with clinical pharmacists playing an active role in refining indication, agent, dose, route, and duration at the individual-patient level.

Initial Assessment and Support to Empirical Prescribing

Evidence from emergency department and ward-based sepsis bundles indicates that participation of clinical pharmacists in sepsis alerts and response teams can shorten time to first antibiotic dose and increase the proportion of patients receiving guideline-concordant empirical regimens.[11]

A second core task at this early stage is verification and, where necessary, clarification of recorded antimicrobial "allergies". Many in-hospital allergy labels, particularly for beta-lactams, represent non-allergic adverse effects, remote childhood rashes, or undocumented reactions, and structured pharmacist-led allergy interviews have been shown to safely de-label a substantial proportion of patients while expanding access to first-line agents. Using standardized tools or templates, pharmacists can differentiate likely IgE-mediated hypersensitivity (for example, immediate urticaria, angio-oedema, bronchospasm, anaphylaxis) from delayed exanthems, intolerances, and idiosyncratic reactions, and can propose either use of preferred beta-lactams, graded challenges, or alternative regimens, in collaboration with allergists when indicated. This meticulous documentation of allergy history directly influences empirical choices and helps avoid unnecessary use of broader-spectrum or more toxic alternatives driven by inaccurate allergy labels.

Building on this structured assessment, pharmacists support empirical prescribing by integrating patient-specific factors with local epidemiology and guideline recommendations. Bedside review typically considers the suspected source of infection, severity (including need for intensive care and presence of septic shock), prior colonization or infection with resistant organisms, recent antimicrobial exposures, comorbidities, and current organ function, particularly renal and hepatic function. Using institution-specific guidelines and antibiograms, pharmacists can recommend empirical regimens that provide adequate coverage for the most likely pathogens and resistance phenotypes while avoiding unnecessary redundancy or excessive spectrum, adjusting doses and dosing intervals for organ dysfunction and altered pharmacokinetics, and identifying candidates for early intravenous-to-oral switch when clinically stable. In settings with formal sepsis pathways or antimicrobial stewardship bundles, pharmacists often document indication, chosen regimen, planned duration, and criteria for de-escalation at the time of prescribing, thereby laying the groundwork for subsequent review at 48–72 hours once microbiology and biomarker results become available.[12]

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[11] Atkins PE, Bastin MLT, Morgan RJ, et al. Pharmacist Involvement in Sepsis Response and Time to Antibiotics: A Systematic Review. J Am Coll Clin Pharm. 2023;6(8):942-953.
[12] https://www.ihmt.unl.pt/wp-content/uploads/2015/10/policy-paper-eng.pdf

WHO AWaRe framework (Access, Watch, Reserve)

The WHO AWaRe framework (Access, Watch, Reserve) is a simple but powerful way of organizing systemic antibiotics to support antimicrobial stewardship at bedside, institutional, and national levels. It was introduced by the WHO Expert Committee on Selection and Use of Essential Medicines to move prescribers and policymakers away from an undifferentiated view of "antibiotics" and toward explicit prioritization of agents with lower resistance potential as first-line choices for common infections. The system currently groups antibiotics into **Access**, **Watch**, and **Reserve** categories, each with a distinct stewardship role, and is regularly updated as new data on resistance, indications, and utilization emerge.

Access antibiotics are those recommended as first- or second-line options for a wide range of common community and hospital infections, selected for their proven efficacy, safety profile, and comparatively lower propensity to select resistance when used appropriately. They are intended to be widely available, and affordable, and WHO has set a target that at least 60% of total national antibiotic consumption should derive from this group.

Watch antibiotics include critically important classes with higher resistance potential or a narrower spectrum of recommended indications (for example, certain third-generation cephalosporins, fluoroquinolones, and macrolides). Their use should be more tightly controlled, monitored, and typically reserved for specific syndromes or risk profiles, making them prime targets for hospital pre-authorization, prospective audit and feedback, and regular reporting by stewardship teams.

Reserve antibiotics are explicitly designated as "last resort" options for confirmed or strongly suspected infections caused by multidrug-resistant organisms, and their use should be highly restricted, often requiring infectious diseases consultation or stewardship approval.

In practice, the AWaRe framework supports a three-step stewardship logic: classify all available antibiotics into AWaRe groups; design local guidelines and empirical treatment pathways that favor Access agents whenever they can provide adequate coverage; and monitor antibiotic consumption and quality indicators using AWaRe categories as a standard reporting unit. For clinical pharmacists, this provides both a didactic language to teach students an "Access-first" mindset and a set of practical levers to align formulary decisions, guideline development, and utilization metrics with global stewardship goals.

- Moja L, Zanichelli V, Mertz D, et al. WHO's essential medicines and AWaRe: recommendations on first- and second-choice antibiotics for empiric treatment of clinical infections. Clin Microbiol Infect. 2024;30 Suppl 2:S1-S51.

Prospective Audit, Feedback, and "Antibiotic Time-Outs"

After the initial 24–72 hours of empirical therapy, a structured reassessment of antimicrobial treatment is one of the most important bedside stewardship activities. Prospective audit and feedback refer to the review of ongoing antimicrobial prescriptions by a stewardship team member, who then provides patient-specific recommendations to the prescriber regarding whether to continue, narrow, switch, or discontinue therapy, and to adjust dose, route, or duration considering new clinical and microbiological information. This reassessment typically occurs once culture results, susceptibility testing, and early biomarker trends (e.g., C-reactive

protein or procalcitonin) are available and the patient's clinical trajectory over the first days has become clearer, making it possible to tailor therapy to documented pathogens or to stop antibiotics altogether when infection is unlikely. Studies including pharmacist-led programs, have consistently shown that such audit and feedback interventions can reduce overall antibiotic exposure, increase de-escalation to narrower-spectrum agents, and improve guideline concordance, often without adverse effects on mortality or length of stay.

In practice, pharmacist-led prospective audit and feedback can be organized according to different models, ranging from focused review of selected high-priority antibiotics or units to comprehensive evaluation of all systemic antimicrobials in a ward or hospital. In a "one-step" model, the pharmacist both performs the chart review and communicates recommendations directly to the treating team. In a "two-step" model, the pharmacist conducts the initial screening and data collection, including review of indication, cultures and susceptibilities, current doses relative to renal and hepatic function, drug-drug interactions, and opportunities for IV-to-oral switch. Whichever configuration is used, the pharmacist's bedside presence and ability to translate microbiology reports and guideline algorithms into concrete regimen changes are key determinants of impact, and audit and feedback programs limited to selected wards or antimicrobials have been shown to produce substantial improvements in use among audited patients even when spill-over to unaudited areas is modest.

The concept of an "**antibiotic time-out**" builds on these principles by encouraging a scheduled pause for reflection at a predefined time point, usually around 48–72 hours after starting antibiotics, during which the clinical team explicitly revisits a small set of core questions about each prescription. At the bedside, pharmacists can prompt and structure these time-outs by asking whether there is still evidence of infection, whether culture results or biomarkers allow narrowing or discontinuation, whether the current spectrum and combination remain necessary, whether the dose and route are appropriate given organ function and clinical stability, and whether a clear plan for total duration and review date has been documented. Time-outs can be implemented informally during daily rounds, through printed or electronic checklists incorporated into progress notes or electronic prescribing systems, or as part of broader sepsis or pneumonia care bundles, and they provide a natural point for pharmacists to negotiate de-escalation, IV-to-oral switch, or early stop dates with prescribers. By embedding this recurrent, pharmacist-facilitated reflection into routine care, prospective audit, feedback, and antibiotic time-outs together transform antimicrobial therapy from a one-off decision at initiation into a dynamic process that responds to evolving diagnostic information and patient status, thereby improving appropriateness while minimizing unnecessary exposure.

De-escalation, Streamlining, and Discontinuation

Once microbiological results and the early clinical trajectory are available, a bedside stewardship task is to **shift from broad empirical coverage to the narrowest effective regimen**, or to stop antibiotics entirely when infection becomes unlikely. **De-escalation** and streamlining can be defined as the process of reducing the spectrum or number of antimicrobials based on culture and susceptibility data, local epidemiology, and the patient's clinical response, while maintaining adequate activity against the causative pathogen. This includes replacing broad-spectrum or combination regimens with a single, narrower agent when feasible, discontinuing empiric agents that were started to "cover all bases" in the initial hours but are no longer indicated once the diagnosis is clarified. Clinical pharmacists are well placed to identify such opportunities during routine ward rounds or structured medication reviews [N.B., Validação da Prescrição], as they routinely integrate laboratory reports, antibiograms, and patient-specific

factors such as organ function, drug–drug interactions, and previous antimicrobial exposures into concrete recommendations for regimen simplification.

Carbapenem de-escalation is a paradigmatic example of this activity. In many hospitals, carbapenems (e.g., imipenem, meropenem) are widely used empirically for suspected severe infections or in patients with risk factors for resistant Gram-negative organisms, yet subsequent microbiology often reveals pathogens that are susceptible to narrower agents, including third-generation cephalosporins, beta-lactam/beta-lactamase inhibitor combinations, or even oral options. Studies have shown that pharmacist-supported carbapenem de-escalation strategies can substantially reduce carbapenem consumption without compromising clinical outcomes such as mortality, length of stay, or recurrence of infection. Pharmacists can operationalize this by maintaining lists of patients receiving carbapenems or other restricted agents, prioritizing them for daily review, and proposing specific alternatives and doses once susceptibilities are available, while also accounting for pharmacokinetic-pharmacodynamic considerations and potential adverse effects.

Discontinuation of antimicrobials when infection becomes unlikely is the other side of this process and is equally important for optimizing therapy and limiting collateral damage. Many patients receive empiric antibiotics for non-specific signs such as fever, leukocytosis, or radiographic abnormalities that later prove to have non-infectious causes or self-limited viral infections, and ongoing therapy often persists by inertia unless someone explicitly revisits the indication. During antibiotic time-outs or prospective audit and feedback sessions, pharmacists can prompt the team to consider stopping treatment altogether when cultures remain negative, biomarkers and clinical status improve, and no convincing source of bacterial infection is identified, thereby preventing unnecessary exposure, selection of resistance, and drug toxicity.

Dose Optimization

Dose optimization at the bedside requires the clinical pharmacist to translate general dosing recommendations into regimens that reflect the patient's current organ function, body size, and physiological status, particularly in critical illness where pharmacokinetics are highly variable. In patients with renal or hepatic dysfunction, pharmacists routinely adjust maintenance doses and dosing intervals of renally or hepatically cleared antimicrobials based on estimated glomerular filtration rate, dynamic changes in renal function, and markers of hepatic impairment, (See Lesson 4: Clinical Pharmacy in Renal and Hepatic Impairment). Extremes of body weight introduce additional complexity: hydrophilic agents with limited tissue distribution often require higher absolute doses or weight-based loading strategies in obesity to achieve adequate serum and tissue concentrations, whereas lipophilic drugs may need more nuanced adjustments, and contemporary reviews provide antimicrobial-specific recommendations that pharmacists can integrate into local dosing guides and bedside practice (See Lesson 5: Clinical Pharmacy in Patients with Extreme Body Size).

Critical illness, augmented renal clearance, and extracorporeal support further challenge standard dosing (See Lesson 8: Clinical Pharmacy in Patients under Renal Replacement Therapy). In many intensive care patients, systemic inflammation, capillary leak, and fluid resuscitation increase the volume of distribution of hydrophilic antibiotics, justifying the use of loading doses to rapidly reach therapeutic concentrations, followed by maintenance dosing adapted to frequently changing renal function and, where present, renal replacement therapy or extracorporeal membrane oxygenation. Augmented renal clearance and renal hyperfiltration, particularly in younger trauma or sepsis patients with high cardiac output, can lead to

subtherapeutic exposure of renally cleared beta-lactams and other agents at conventional doses; pharmacists therefore play an important role in identifying such patients, often by monitoring creatinine clearance or urine output, and in proposing higher or more frequent dosing regimens guided by pharmacokinetic–pharmacodynamic principles and, when available, therapeutic drug monitoring. For patients on continuous or intermittent renal replacement therapy, structured approaches that consider modality, effluent flow, membrane characteristics, and residual renal function are needed, and detailed dosing frameworks emphasize the value of higher initial doses and subsequent individualization based on clinical response and drug levels.

At the bedside, pharmacist-led therapeutic drug monitoring for agents with narrow therapeutic indices, particularly vancomycin and aminoglycosides, involves requesting or validating appropriate sampling times, interpreting serum concentrations considering pharmacokinetic parameters and current guidelines, and recommending dose and interval adjustments together with the timing of follow-up levels to maintain exposures within defined efficacy and safety targets. In parallel, pharmacists systematically screen antimicrobial regimens for nephrotoxicity, ototoxicity, hepatotoxicity, QT-interval prolongation, myelosuppression, and other clinically important adverse effects, reviewing concurrent nephrotoxins or QT-prolonging agents, monitoring relevant laboratory and ECG parameters, and proposing alternative therapies or mitigation strategies when overlapping toxicities or drug–drug interactions place patients at increased risk. TDM is further explored in Biopharmacy and Pharmacokinetics course (4th year).

Intravenous-to-oral Switch and Route Optimization

Intravenous-to-oral switch programs are now recognized as a core component of antimicrobial stewardship, and clinical pharmacists frequently lead or initiate these interventions at the bedside. Studies indicate that, in clinically stable inpatients with a functioning gastrointestinal tract and without infections that mandate prolonged intravenous therapy (e.g., endocarditis, meningitis, undrained deep-seated infections), **timely IV-to-oral switch is safe and associated with reduced length of stay, fewer catheter-related complications, lower nursing workload, and decreased antimicrobial costs**, without compromising cure rates. Pharmacist-driven protocols generally define explicit eligibility criteria, including hemodynamic stability, improving clinical signs and inflammatory markers, absence of persistent vomiting or malabsorption, ability to swallow or receive enteral medication, and availability of an appropriate oral agent with adequate bioavailability and spectrum.[13]

Selection of oral agents and dosing requires careful attention to equivalence of spectrum and pharmacokinetic properties. For some antibiotics, such as fluoroquinolones, linezolid, or certain macrolides, high oral bioavailability allows straightforward 1:1 conversion from intravenous to oral dosing, whereas for others, including many beta-lactams, higher or more frequent oral doses may be necessary to achieve similar exposures, and the pharmacist's knowledge of drug-specific bioavailability, food effects, and formulary options is critical.

[13] Harvey EJ, McLeod M, De Brún C, Ashiru-Oredope D. Criteria to achieve safe antimicrobial intravenous-to-oral switch in hospitalised adult populations: a systematic rapid review. BMJ Open. 2023;13(7):e068299.

11.3 Monitoring Outcomes and Feeding Back to Clinical Teams

As bedside stewardship activities mature, their impact depends on the ability to translate individual interventions into meaningful epidemiological information and quality indicators that can be shared with clinical teams and hospital leadership. Clinical pharmacists should be central to this process because they understand both the pharmacotherapy decisions made at the bedside and the structure of local data systems, enabling them to bridge between patient-level optimization and service-level measurement of antimicrobial use and outcomes. In many programs, pharmacists help define and track key indicators such as guideline adherence, days of therapy per 1 000 patient-days, de-escalation rates, proportion of intravenous-to-oral switches, and selected clinical endpoints (for example, length of stay, Clostridioides difficile infection, or readmissions related to infection), which together provide a quantitative picture of how rational antibiotic use policies are functioning over time.[14] Metrics to evaluate drug utilization will be further explored in Pharmacoepidemiology and Pharmacovigilance course (5th year).

From an epidemiological perspective, routine aggregation and analysis of antimicrobial utilization and resistance data supports the design and adjustment of local antibiotic policies. Pharmacists frequently participate in constructing **ward- and hospital-level antibiograms**, stratified where appropriate by location or population, and in linking these to consumption metrics such as days of therapy or defined daily doses (DDD), thereby helping to identify areas of overuse, shifts in empirical treatment pressures, and potential associations with emerging resistance patterns. In collaboration with microbiology, infection prevention, and hospital epidemiology, they contribute to periodic reports that compare utilization and quality indicators across wards or services, highlight high-impact problem areas (for example, persistent broad-spectrum carbapenem use in a specific intensive care unit, or low de-escalation rates in surgical wards), and inform updates to local guidelines and formulary restrictions. **These epidemiological analyses move stewardship beyond case-by-case interventions**, embedding it within a broader policy framework for rational antimicrobial use at institutional and, when aggregated, regional level.

At ward level, clinical pharmacists often design and implement simple audit tools that focus on a small number of prescribing behaviors linked to best practice and local priorities. Quality improvement guidance emphasizes limiting such audits to a manageable sample size and a concise set of variables —such as compliance with guideline-recommended first-line agents, timely review at 48–72 hours, or presence of a planned stop date— so that they can be repeated regularly and used as part of **plan–do–study–act cycles**. Pharmacists may develop paper or electronic forms to capture these data during routine ward rounds, or extract them retrospectively from electronic prescribing systems, coding each intervention in a way that facilitates aggregation and analysis.

Feeding back results to clinical teams is a critical step in closing the audit loop and sustaining change in prescribing behavior. Studies indicate that feedback is most effective when it is timely, ward-specific, and framed in terms that clinicians perceive as relevant to patient care, rather than abstract consumption alone. Pharmacists contribute by preparing concise, visually clear summaries and presenting these at ward meetings, morbidity and mortality reviews, or

[14] Dighriri IM, Alnomci BA, Aljahdali MM, et al. The Role of Clinical Pharmacists in Antimicrobial Stewardship Programs (ASPs): A Systematic Review. Cureus. 2023;15(12):e50151.

multidisciplinary teaching sessions. Where feasible, feedback can be tailored to specific specialties or even to individual prescribers, for example by showing their antimicrobial use relative to peers or their rates of documented indication, but always within a non-punitive, quality-improvement framework that encourages discussion and co-ownership of solutions.