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Guideline for antibacterial therapy of adult community-acquired pneumonia in the emergency department under the physician-pharmacist collaborative management model

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Abstract

Community-acquired pneumonia (CAP) in adults (≥18 years old) is the most common infectious disease encountered in emergency departments. Its clinical complexity and the need for prompt treatment decisions pose significant challenges for patient management. The physician-pharmacist collaborative management (PPCM) model, which optimizes drug therapy regimens through collaboration between physicians and clinical pharmacists, has demonstrated strong clinical value in practice. However, the lack of standardized national guidelines for the application of the PPCM model in emergency departments in China has hampered its widespread adoption. This guideline is developed based on evidence-based medicine and clinical practice experience, with a focus on the application of the PPCM model in the management of CAP in emergency settings. It outlines the significance of the PPCM model, its applicable scenarios, the respective roles of emergency physicians and clinical pharmacists, and its practical implementation in the antimicrobial treatment of CAP patients. In addition, the guideline proposes standardized implementation processes and clinical pathways. By promoting the PPCM model, the expert panel aims to standardize the use of antimicrobial agents in the emergency treatment of CAP, reduce the risk of antimicrobial resistance, and improve patient outcomes.

Keywords: Antibacterial therapy, Clinical pharmacists, Community-acquired pneumonia, Emergency, Physician-pharmacist collaborative management

Background

The physician-pharmacist collaborative management (PPCM) model is a medical approach in which physicians and clinical pharmacists jointly participate in the therapeutic management of patients, with the goal of improving outcomes and safety by optimizing drug therapy regimens. Emergency medicine requires that medical staff make prompt, accurate diagnoses and treatment decisions for critically ill patients facing complex and diverse clinical problems. Studies have shown that actively involving clinical pharmacists in the therapeutic management of emergency patients can help optimize drug therapy and improve treatment outcomes.[1] In recent years, the PPCM model in emergency departments has been increasingly used, and steadily incorporated into pharmaceutical services in this setting.

China's clinical pharmacist system has been gradually promoted since it was first proposed by the Ministry of Health in 2002. Pilot programs were launched at 42 tertiary care hospitals from 2007. The Provisions on Pharmaceutical Affairs Administration of Medical Institutions, promulgated in 2011, further clarified the responsibilities of clinical pharmacists and supported the shift in pharmaceutical services from traditional drug supply roles to patient-centered

All data generated or analyzed during this study are included in this published article and its supplementary information files.

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clinical practices.[2] However, the lack of practical guidelines for implementing the PPCM model in emergency departments continues to limit its broader adoption and application in China's emergency settings.

In the past decade, the number of emergency department visits in China has tripled, reaching 166.5 million.[3] Respiratory infections are the leading cause of these visits, with community-acquired pneumonia (CAP) being particularly common.[4] Approximately 75% of patients with CAP receive their initial diagnosis and treatment in the emergency department.[5] Emergency physicians must make rapid diagnostic and antibacterial treatment decisions, often without microbiological evidence. In recent years, the approval of novel antibacterial agents in China, such as lefamulin, omadacycline, and ceftobiprole, has expanded therapeutic options in clinical practice, but has also brought about new challenges in the precise use of these agents. Selecting an appropriate antibacterial agent requires consideration of multiple factors, including the patient's age, comorbidities, medication history, and drug sensitivity. Moreover, developing individualized medication strategies for special populations—such as the elderly, immunocompromised patients, and those with hepatic or renal impairment—remains an urgent clinical challenge. The introduction of the PPCM model offers a promising solution for managing CAP in the emergency department. This approach not only helps optimize therapeutic regimens but also promotes rational antibiotic use and reduces the risk of drug resistance.

In this context, the present guideline establishes a PPCM model for antimicrobial therapy in emergency management of CAP, based on evidence from evidence-based medicine supplemented by expert consensus. During the development process, evidence-based recommendations were formulated for clinical questions, supported by high-quality and consistent evidence. For clinical questions where current evidence was limited or inconclusive, consensus-based recommendations were developed through discussions between emergency physicians and clinical pharmacists, grounded in clinical experience. This guideline aims to promote the PPCM model in the emergency treatment of CAP, with the goals of improving antibacterial treatment and the prognosis of patients with CAP in emergency care.

Methods

Initiators and expert group members

This guideline was jointly initiated by Society of Emergency Medicine of Chinese Medical Association and Emergency Medicine Branch of the Chinese Geriatrics Society, with participation from experts in fields such as emergency medicine, respiratory and critical care medicine, pharmacy, infectious disease, and microbiology. The development of this guideline began in October 2024 and was completed in May 2025. The guideline is registered with Guidelines-registry.cn (PREPARE-2024CN982).

Evidence retrieval

Members of the authoring group retrieved and screened relevant literature from databases including PubMed, Embase, CNKI, and Wanfang Data, from database inception through April 2025. Major search terms included physician-pharmacist collaborative drug therapy management, PPCM, CAP, and antimicrobial stewardship. Eligible publications included meta-analyses, systematic reviews, randomized controlled trials, retrospective studies, case series, and guidelines or expert consensus documents.

Classification of quality of evidence and strength of recommendations

The strength of recommendations and levels of evidence used in this guideline are presented in Table 1.[6]

Importance of PPCM model in the treatment of CAP at the emergency department

Characteristics of diagnosis and treatment of CAP in emergency care

The clinical manifestations of CAP in emergency patients often lack typical features. The detection rate of pathogens remains low,[7,8] and the consistency between admission diagnoses and discharge diagnoses is also poor.[9] In terms of treatment, the initial management of emergency patients with CAP relies heavily on empirical antibacterial therapy, but significant challenges persist. Studies have shown that approximately 25%–50% of antibiotic prescriptions in emergency care are irrational, and the medication error rate is relatively high.[10] It is also noteworthy that the use of broad-spectrum antibiotics and injectable antibiotics among emergency patients in China is high.[11] Furthermore, adherence to guidelines for the use of antibacterial drugs among emergency patients with CAP remains generally low across various countries and urgently needs improvement.[12–14] Given the urgency of medical care in the emergency setting, emergency physicians often must make rapid diagnoses and anti-infective treatment decisions without etiological evidence, posing a major challenge to the standardization and rationality of drug therapy.

Table 1

Strength of Recommendations and Levels of Evidence

Category	Description
Strength of recommendations	Level I: Based on level A evidence or highly consistent consensus among experts
	Level II: Based on level B evidence and/or expert consensus
	Level III: Based on level C evidence and/or expert consensus
	Level IV: Based on level D evidence and/or expert consensus
Levels of evidence	Level A: Meta-analysis or systematic evaluation of multiple randomized controlled trials; multiple randomized controlled trials or 1 high-quality randomized controlled trial with an adequate sample size; multiple or 1 prospective cohort study (high-quality) with an adequate sample size and a blind evaluation
	Level B: At least 1 relatively high-quality randomized controlled trial; based on at least 1 prospective cohort study or well-designed retrospective case-control study (relatively high quality)
	Level C: Well-designed controlled trials that are not randomized or well-designed cohort studies or case-control studies
	Level D: Case series analysis without concurrent controls, expert consensus or comments

Impact of PPCM model on treatment of CAP in emergency care

The PPCM model has played a positive role in the treatment of CAP in emergency care. Studies have shown that clinical pharmacists can significantly improve adherence to antimicrobial prescribing guidelines for patients with CAP. One study confirmed that clinical pharmacist involvement increased the guideline-concordant rate of empirical antibiotic prescriptions for patients with CAP from 79% to 95%.[15] Additionally, a meta-analysis showed that the proportion of patients with CAP receiving appropriate antibiotic prescriptions increased significantly following clinical pharmacist intervention (odds ratio, 3.74; 95% confidence interval, 2.14 to 6.54).[16] Clinical pharmacists have also been shown to improve the appropriateness of antibiotic therapy, dosage, and duration by reviewing culture reports and initiating adjustments to antibacterial regimens, which in turn shortens the duration of therapy and reduces total antibiotic use.[17,18] Moreover, studies indicate that drug-related tasks occupy 8.7% to 17.8% of emergency physician's working time,[19,20] and the PPCM model helps alleviate this burden, allowing emergency physicians to focus more on core clinical duties.[21] Overall, the PPCM model has significantly enhanced the treatment of emergency patients with CAP by optimizing therapeutic regimens, improving treatment efficiency, and promoting the rational use of medical resources.

Recommendation 1: The PPCM model is an important approach to standardizing the treatment of CAP and improving patient outcomes. In the therapeutic management of CAP in emergency care, medical institutions are recommended to actively promote the PPCM model (level II recommendation, level B evidence).

Types and application scenarios of PPCM model

Pre-prescription review

Pre-prescription review is a prescription quality control process led by the pharmacist as the primary responsible party. Its core goal is to promptly detect and correct problematic prescriptions through a real-time review mechanism, ensuring the legality, standardization, and appropriateness of prescriptions.[22] Currently, most medical institutions in China adopt a dual-mode prescription review system, combining both automated and manual review processes ("system review + manual review").[23] In the management of antimicrobial drugs, a computerized decision support system (CDSS) is widely used for pre-prescription review.[24] When an emergency physician prescribes therapy for a patient with CAP, the CDSS provides real-time monitoring of key factors such as dosage range, target population, potential drug interactions, and the rational use of antibiotics for different pathogens. If the system identifies a potentially problematic prescription, it immediately alerts the clinical pharmacist, who then conducts a manual review to prevent misjudgment or negligence.

Pharmaceutical ward round

Pharmaceutical ward rounds refer to rounds conducted by clinical pharmacists with the goal of ensuring the safe, rational, and effective use of medications. These may include independent rounds by clinical pharmacists or joint rounds with other medical staff, such as physicians and nurses.[25] In the management of emergency patients with CAP, clinical pharmacists should be actively involved in pharmaceutical ward rounds, focusing on reviewing the rational use of antibiotics in these patients. When issues related to drug selection, dosage, or treatment duration are identified, the clinical pharmacist should promptly communicate with the emergency physician and provide recommendations to optimize the treatment regimen, ensuring that it aligns with evidence-based medicine and relevant guidelines.[26,27]

Pharmaceutical consultation

In the treatment of complicated cases of CAP, clinical pharmacists may be consulted in the following scenarios: patients with multidrug-resistant bacterial infections; patients with pre-existing conditions such as diabetes mellitus, hypertension, or cardiac disease; patients with poor therapeutic efficacy or recurrent illness; patients requiring special-grade antibiotics.[28,29] The routine pharmaceutical consultation process typically includes the emergency physician submitting a consultation request, followed by the clinical pharmacist providing professional recommendations on drug selection, dosage, and administration frequency based on the patient's condition and the best available evidence. The emergency physician then makes the final decision on the treatment regimen after a comprehensive evaluation.[30–32] Currently, pharmaceutical consultation in China's medical institutions remains in its early stages and lacks unified, standardized procedures.

Case discussion

Case discussion is a key component of the PPCM model, supporting knowledge sharing and improving the overall quality of diagnosis and treatment. In discussions involving patients with CAP, the clinical pharmacist collaborates with the emergency physician, nurses, and other relevant medical staff to review and refine medication regimens.[33] The clinical pharmacist listens to the patient's medical history, conducts a comprehensive analysis based on bedside consultations and diagnostic results, proposes medication recommendations, and completes the consultation record sheet for archiving. This process ensures the traceability of decisions and supports the continuous optimization of the treatment regimen.[34]

Multidisciplinary treatment (MDT)

MDT plays a key role in the treatment of emergency patients with complicated CAP. The MDT team consists of multidisciplinary professionals, including emergency medicine specialists, respiratory medicine specialists, infectious disease specialists, clinical pharmacists, imaging specialists, laboratory medicine specialists, and nurses.[27,35] The Notice on Continuously Improving the Work Related to the Management of Clinical Application of Antimicrobial Drugs, issued by the National Health Commission in 2018, highlights the positive role of clinical pharmacists in multidisciplinary consultations for infectious diseases. Today, clinical pharmacists have become an indispensable part of multidisciplinary emergency medical practice.[36] In the MDT process, clinical pharmacists are deeply involved in discussions and decision-making, working closely with experts from other disciplines to jointly develop personalized, comprehensive treatment regimens.

Integrated application of artificial intelligence (AI) technology and treatment decision support

With the rapid development of AI technology, its applications in the medical field continue to expand. Studies have shown that AI-based clinical decision support systems can enhance the efficiency of clinical decision-making by integrating multi-source data, such as electronic medical records, and providing real-time analysis capabilities.[37] In addition, emerging technologies—particularly large language models—are increasingly being applied to areas such as medical record management and clinical knowledge updates.[38] Within the PPCM model, AI technologies can empower physicians and pharmacists to more efficiently integrate information and improve patient outcomes.

Recommendation 2: In the therapeutic management of emergency patients with CAP, it is recommended to fully leverage the role of clinical pharmacists in pre-prescription reviews, pharmaceutical

ward rounds, case discussions, pharmaceutical consultations, and in AI- and MDT-supported diagnosis and treatment (level IV recommendation, level D evidence).

Recommendation 3: It is recommended to use a CDSS as the core tool for pre-prescription reviews to monitor the rationality of prescriptions for emergency patients with CAP in real time (level I recommendation, level A evidence).

Responsibilities of emergency physicians and clinical pharmacists in antibacterial therapy under the PPCM model

Responsibilities of emergency physicians in antibacterial therapy

Emergency physicians are required to complete standardized training for resident physicians and pass the relevant examinations, equipping them with the basic competencies to independently manage common emergency conditions.[39,40] In addition, according to the Regulations on the Management of Clinical Application of Antibiotics issued by the National Health and Family Planning Commission in 2012, emergency physicians must undergo annual training on the rational use of antibiotics and pass a corresponding examination before they are authorized to prescribe antibiotics.[41] Under the PPCM model, emergency physicians are responsible for diagnosis, condition assessment, and prescribing for patients with CAP, and they should adhere to the first-visit responsibility system.[39,42] For patients with complicated infections, emergency physicians are expected to initiate pharmaceutical consultations and case discussions, and make the final decision on whether to adopt treatment recommendations.[31]

Recommendation 4: Under the PPCM model, emergency physicians should take the lead in treatment decision-making for patients with CAP. In well-qualified medical institutions, emergency physicians are encouraged to actively collaborate with clinical pharmacists to optimize therapy regimens; however, all suggestions provided by clinical pharmacists must be comprehensively evaluated by emergency physicians before implementation (level IV recommendation, level D evidence).

Responsibilities of clinical pharmacists in antibacterial therapy

First, clinical pharmacists should complete standardized training programs in infectious diseases, emergency medicine, intensive care, or respiratory medicine organized by national health authorities or professional associations, and obtain the corresponding "Clinical Pharmacist Training Certificate." In addition, clinical pharmacists from other specialties are required to undergo at least three months of systematic antimicrobial stewardship training and clinical practice, and may only participate in related activities upon passing the assessment.[31]

As a collaborator of the emergency physician in the drug therapy of patients with CAP, the clinical pharmacist is granted specific clinical authority and bears significant responsibilities.[15,43–46] During the treatment period, the clinical pharmacist reviews diagnoses, prescriptions, and medical advice by communicating with medical staff and reviewing medical records. This includes, but is not limited to, assessing drug indications and contraindications, dosages, drug interactions, the rationality of prescribed regimens, and pathogen-drug matching. When necessary, the clinical pharmacist may make recommendations for medication reconciliation and provide pharmaceutical care—such as monitoring for drug reactions and adverse drug events—and regularly evaluate pulmonary function, imaging results, blood drug concentrations, biochemical indicators, and other clinical parameters. Although clinical pharmacists do not participate directly in diagnosis, they provide personalized drug adjustment plans and medication recommendations for patients with adverse reactions, complications, or poor treatment responses by guiding physician decisions and implementing systemic interventions. Additionally, clinical pharmacists may interact directly with patients to help them better understand their condition and explain the scientific rationale and necessity of treatment measures. This can effectively reduce patient fear and anxiety, improve treatment compliance, and support medication education for post-discharge care. At the conclusion of treatment, the clinical pharmacist reviews and comments on discharge prescriptions for patients with CAP, tracks the results of etiological tests post-discharge, conducts follow-up visits, and offers consultation and guidance on post-discharge medication use.

Recommendation 5: In the management of emergency patients with CAP, the primary responsibilities of the clinical pharmacist include assisting the emergency physician in optimizing therapy regimens, conducting prescription reviews, implementing pharmaceutical monitoring, and adjusting individualized drug dosages. In addition, the clinical pharmacist should provide patient medication education, offer pharmaceutical guidance after discharge, and review discharge prescriptions (level I recommendation, level A evidence).

Treatment of CAP in emergency care under the PPCM model

Target population and intervention time of PPCM

For emergency patients with CAP who are at high risk of treatment failure, have failed initial empirical therapy, or require clinical pharmacy services, clinical pharmacists should be involved in their therapeutic management. The target population for the PPCM model in emergency care includes, but is not limited to, the following types of patients: (1) patients with specific pathophysiological characteristics, such as elderly patients (≥65 years old), and those with organ dysfunction (eg. hepatic or renal impairment), immunosuppression, or cognitive impairment; (2) patients with specific disease characteristics, including patients with severe CAP, drug-resistant bacterial infections or risk thereof, unclear pathogen etiology, pre-existing diseases, or complications such as sepsis, respiratory failure, or acute respiratory distress syndrome; (3) patients with specific medication characteristics, particularly those on long-term polypharmacy regimens.[47–51]

The intervention process under the PPCM model is divided into two stages: initial intervention and re-intervention. The initial intervention targets patients who meet the diagnostic criteria for severe CAP, are at high risk of infection with drug-resistant bacteria, require urgent medication reconciliation, or present potential medication risks. Re-intervention is intended for patients who have failed initial therapy, have drug-resistant bacterial infections, experience pathogen-drug mismatches, or develop drug-related adverse reactions during treatment. Additionally, based on the patient's therapeutic response and the results of prescription reviews, the clinical pharmacist should intervene in a timely manner to ensure prompt optimization and adjustment of the treatment regimen.

Recommendation 6: For emergency patients with CAP who have high risk factors for treatment failure—such as advanced age, severe CAP, immunosuppression, risk of infection with drug-resistant bacteria, pregnancy, or use of multiple drug combinations—or who have failed initial empirical therapy, it is recommended to establish conditions for implementing the PPCM model for antibacterial treatment (level IV recommendation, level D evidence).

Locations of intervention of PPCM

Diagnosis and treatment settings for emergency patients with CAP include the emergency department, observation rooms, inpatient

wards, and intensive care units (ICUs).[48] When an emergency patient has questions or concerns about medication, the clinical pharmacist should promptly initiate a medication evaluation to provide consultation and education. For patients with CAP who are under observation, hospitalized, or admitted to the ICU, the clinical pharmacist should further intervene by providing pharmaceutical care and adjusting medication regimens as needed. The clinical pharmacist should also closely review and monitor pathogen culture results to continuously optimize antibacterial treatment strategies.[25]

Recommendation 7: In medical institutions that are well-qualified to implement the PPCM model, it is recommended to assign clinical pharmacists to provide pharmaceutical services for patients with CAP in emergency departments, observation areas, inpatient wards, and ICUs (level IV recommendation, level D evidence).

Implementation process of PPCM model for CAP in emergency care

In the diagnosis and treatment of CAP in emergency care, the implementation of the PPCM model generally follows three stages (Fig. 1): diagnostic evaluation, therapy management, and follow-up. During the diagnostic evaluation stage, the emergency physician is responsible for diagnosing the disease and assessing the patient's condition, determining the appropriate treatment setting based on severity indicators such as the CURB-65 (confusion, uremia, respiratory rate, blood pressure, age ≥65 years) and pneumonia severity index (PSI) scores. In the therapy management stage, the emergency physician formulates an initial empirical antibacterial regimen based on the patient's clinical presentation, etiological test results, and local epidemiological data on drug-resistant bacteria. The clinical pharmacist plays a critical role in this stage by reviewing the rationality of prescriptions—ensuring that drug type, dosage, route of administration, and treatment duration align with clinical guidelines. The clinical pharmacist also actively participates in pharmaceutical consultations, ward rounds, case discussions, and MDT sessions, offering professional pharmaceutical support. Once the PPCM model is implemented, the clinical pharmacist conducts pharmaceutical monitoring, regularly assesses the patient's treatment response, monitors for adverse drug reactions and etiological findings, and recommends therapy adjustments based on these evaluations. Final treatment decisions are made by the emergency physician after comprehensive assessment. During the follow-up stage, the clinical pharmacist provides medication guidance to discharged patients, monitors treatment outcomes, and collects and analyzes data related to antibiotic use.[43,52]

Recommendation 8: The PPCM model should be implemented throughout the treatment and follow-up of emergency patients with CAP to improve clinical efficacy and prognosis through the

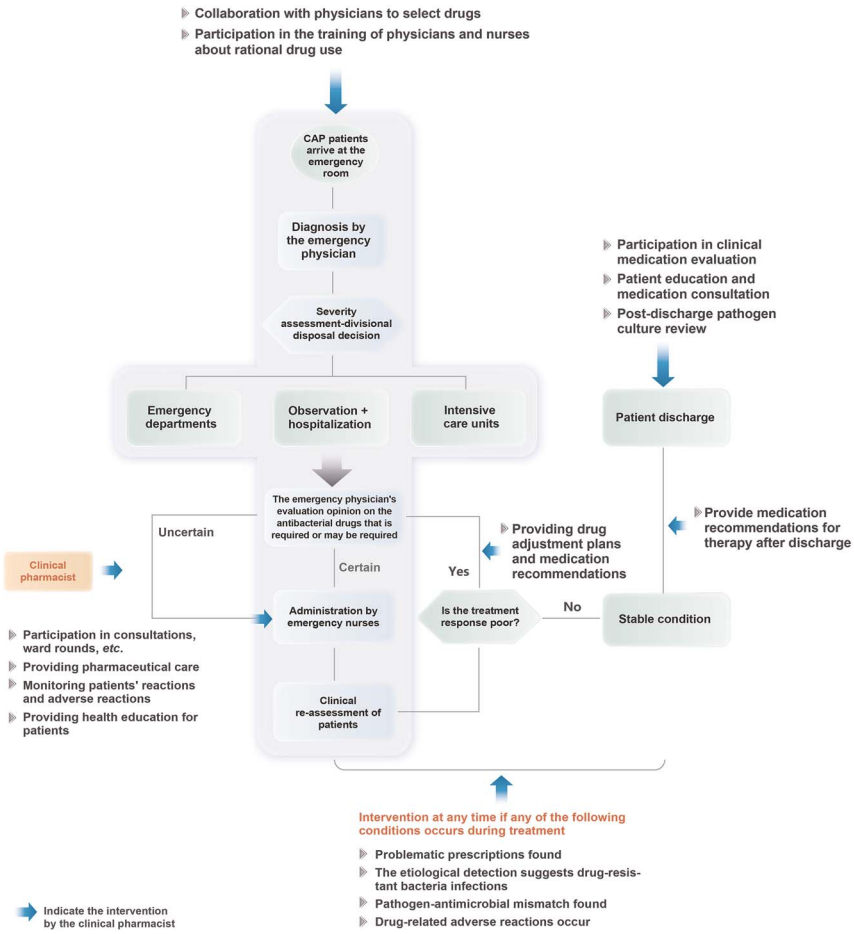

Figure 1. Implementation process of PPCM model for emergency patients with CAP. CAP, community-acquired pneumonia; PPCM, physician-pharmacist collaborative management.

continuous optimization of therapy regimens and dynamic monitoring of treatment effectiveness (level IV recommendation, level D evidence).

Application of PPCM model in antibacterial treatment of special CAP patients

Elderly patients with CAP. CAP in elderly patients (≥65 years old) is a common infectious disease marked by high incidence and complex clinical features. It often presents with an insidious onset, atypical symptoms, rapid progression, and a tendency to cause sequelae or progress to severe pneumonia. Because of physiological degeneration in tissues and organs, elderly population typically has reduced capacities for drug absorption, metabolism, and excretion. They are also frequently affected by underlying conditions, making polypharmacy a common occurrence.[48,53] As a result, the drug treatment regimens for elderly patients with CAP are often complex and require a higher standard of medication therapy management. Studies have shown that clinical pharmacist-led medication therapy management and medication review significantly reduce hospitalizations and drug-related problems in elderly patients.[54–56] When prescribing antibacterial agents for elderly patients with CAP, particular attention should be paid to drug safety. Agents with both strong antibacterial efficacy and favorable safety profiles should be prioritized to reduce the risk of adverse reactions (Table 2). Furthermore, etiological diagnosis of CAP in elderly population is more challenging. It is important to distinguish between true pathogens and bacterial colonization or contamination to avoid misdiagnosis.[53] Therefore, for elderly patients with CAP in the emergency treatment, clinical pharmacist involvement in reviewing and following up on etiological diagnoses should be actively promoted to ensure the accuracy and rationality of the antibacterial treatment regimen.

For elderly patients with CAP without other underlying comorbidities, the recommended antimicrobial agents include second- or third-generation cephalosporins in combination with a macrolide (eg. azithromycin) or a tetracycline (eg. minocycline or doxycycline), amoxicillin/clavulanate, respiratory fluoroquinolones (eg. levofloxacin, moxifloxacin, or nemonoxacin), third-generation tetracyclines (eg, omadacycline), or pleuromutilins (eg. lefamulin). However, it should be noted that β-lactam antibiotics alone do not provide coverage against atypical pathogens. In China, resistance rates of *Streptococcus pneumoniae* and *Mycoplasma pneumoniae* to macrolides exceed 80%.[57–59] The safety of some quinolones in elderly population is a particular concern because these drugs may cause QT interval prolongation and other adverse effects. Omadacycline should also be used with caution in patients at high risk of mortality, as indicated in its package insert.[60] These limitations highlight the urgent need for safer and more effective treatment options for elderly patients with CAP. Lefamulin, a novel antibacterial agent with a unique mechanism of action, has been proven in multiple clinical trials to be safe and effective in elderly patients and those with comorbidities. Moreover, its recommended treatment duration is 5 to 7 days, which is shorter than that of many other antibiotics, offering a new therapeutic option for elderly patients with CAP.[61–63]

Recommendation 9: For elderly patients with CAP, it is recommended that clinical pharmacists be involved in optimizing the antibacterial treatment regimen (level II recommendation, level B evidence). The treatment regimen should cover both common pathogens and atypical organisms, include an assessment of resistance risk, consider novel antibacterial agents with lower resistance potential, and ensure close monitoring for adverse drug reactions (level I recommendation, level A evidence).

Immunocompromised patients with CAP. Among patients with CAP, approximately 10% to 18% are immunocompromised (Table 3); these individuals are classified as having CAP in immunocompromised patients (ICP-CAP).[64,65] The pathogens in ICP-CAP cases are complex, with susceptibility to common bacterial infections, mixed infections, and opportunistic infections.[66] Due to their compromised immune function, patients receiving long-term broad-spectrum antibacterial therapy are at increased risk of drug resistance and adverse reactions. Introducing the PPCM model to optimize antibacterial strategies for ICP-CAP patients offers clear advantages. In this model, the emergency physician is responsible for assessing the patient's immune function to identify ICP-CAP cases and for initiating the initial antibacterial treatment regimen. According to the results of etiological exams, pathogen cultures,

Table 2

Usage Risk and Common Adverse Reactions of Commonly Used Antibacterials in Elderly Patients With CAP

Class of Antibacterial Agents	Risk Indication/Common Adverse Reactions in Elderly Patients
Penicillins, cephalosporins, β-lactam/β-lactamase inhibitor mixtures	• Atypical pathogens cannot be covered by drug monotherapy, so it is often used in combination with macrolides or quinolones • Penicillin skin test to limit the scope of use
Tetracyclines	• Due to the high resistance rate of *Streptococcus pneumoniae* to doxycycline/minocycline, monotherapy is not recommended for elderly patients who are at high risk of drug-resistant *Streptococcus pneumoniae* infection (especially those with underlying comorbidities) • Clinical data showed that in the phase III trial of omadacycline, there were 8 deaths (2%)—twice that of the control group—and all occurred in patients >65 years old, raising concerns of mortality imbalance. Omadacycline should be used with caution in elderly patients at high risk of death
Macrolides	• It is recommended for empirical treatment of CAP only in regions with low resistance rates. Due to the high resistance of *Streptococcus pneumoniae* and *Mycoplasma pneumoniae* in China, it should be used with caution in elderly patients
Quinolones	• There is a high rate of serious adverse reactions (eg. tendinitis, QT prolongation, central neurotoxicity). U.S. FDA has issued a boxed warning about cardiovascular, neurological, and glycemic risks, which are generally further increased in patients >60 years of age, requiring a rigorous benefit-risk assessment • The UK Medicines and Healthcare products Regulatory Agency states it should only be used when other antibacterial agents are unsuitable • In China, it is emphasized that some elderly patients are intolerant to quinolones, thus requiring caution in use among the elderly.
Pleuromutilins	• The most common adverse reactions (≥2%) are administration site reaction, diarrhea, nausea, vomiting, and liver enzymes increased, and the symptoms are mild and manageable. Elderly patients have a similar adverse reaction profile compared to patients <65 years of age

CAP, community-acquired pneumonia; FDA, Food and Drug Administration.

Table 3

Immunocompromised Patients

Patient Conditions
Neutropenia (<500/mL)
Receiving cancer chemotherapy
Leukemia
HIV-infected (CD4 < 200/mL)
Solid organ transplantation
Hematopoietic stem cell transplantation
Receiving corticosteroid therapy (dose ≥20 mg/d prednisone or duration ≥14 d)
Receiving immunosuppressive therapy

and drug sensitivity tests, the clinical pharmacist should conduct real-time monitoring of the antibacterial regimen and offer recommendations for optimization and adjustment when necessary. The PPCM model improves the timeliness and effectiveness of de-escalation therapy and enhances the accuracy and individualization of antibacterial treatment in ICP-CAP patients.

Recommendation 10: For patients with ICP-CAP, it is recommended to actively involve clinical pharmacists in assisting emergency physicians with monitoring microbiological results and treatment response, to enable timely adjustment of antibacterial therapy and ensure treatment accuracy (level IV recommendation, level D evidence).

Patients with CAP and coexisting hepatic and renal impairment. In the emergency management of patients with CAP and coexisting hepatic and renal impairment, it is essential to consider the pharmacokinetic characteristics and potential hepatonephrotoxicity of antibacterial agents.[67,68] Antibacterial selection and dosing must be rationally tailored to ensure therapeutic efficacy while minimizing the risk of adverse effects (Table 4). Agents with minimal or no hepatorenal toxicity should be prioritized. The dosage should be adjusted according to the drug's elimination pathways, and an individualized dosing regimen should be developed. It is recommended to initiate the PPCM model early in the treatment process. The emergency physician should evaluate liver and kidney function, while the clinical pharmacist incorporates these assessments along with pharmacokinetic data to provide personalized recommendations for antibacterial selection and dose adjustment. Throughout treatment, the emergency physician and clinical pharmacist should closely monitor changes in the patient's condition and dynamically optimize the medication regimen. For antibacterial agents requiring plasma concentration monitoring, the clinical pharmacist can assist the emergency physician with therapeutic drug monitoring (TDM) and guide precise dose adjustments.

Recommendation 11: For emergency patients with CAP and hepatic or renal impairment, antibacterial agents with minimal or no hepatonephrotoxicity should be prioritized, and dosages should be adjusted based on the drug's elimination pathways. It is recommended that clinical pharmacists be actively involved in assisting emergency physicians with individualized dose adjustments to ensure treatment efficacy and reduce the risk of toxicity (level IV recommendation, level D evidence).

Patients with CAP on continuous renal replacement therapy (CRRT). In patients undergoing CRRT, the unique drug clearance mechanisms involved can significantly affect the pharmacokinetics and pharmacodynamics (PK/PD) of antibacterial agents. To reduce the risk of treatment failure and the development of drug resistance, the PPCM model should be introduced to help optimize the antibacterial treatment regimen. Dose adjustment strategies should be personalized based on the CRRT modality, the pharmacological characteristics of the antibacterial agents, and patient-specific factors. It is recommended to prioritize agents that are primarily non–renally eliminated or minimally cleared *via* CRRT (eg. ceftriaxone, moxifloxacin, omadacycline, lefamulin, azithromycin) because these agents are more likely to maintain effective plasma concentrations. For patients with severe CAP, the treatment regimen should be further tailored based on the minimum inhibitory concentrations of pathogens and the patient's organ function. PK/PD target values should be adjusted according to TDM.[69] Within the PPCM model, the emergency physician should adjust the treatment regimen in real time based on the clinical pharmacist's recommendations and the patient's clinical response, achieving a more precise and individualized approach to therapy.

Recommendation 12: For patients with CAP receiving CRRT, antibacterial agents that are primarily non–renally eliminated or minimally affected by CRRT are preferred. Clinical pharmacists should assist emergency physicians in calculating and recommending appropriate dosages based on the CRRT modality and patient-specific factors (level IV recommendation, level D evidence).

Patients with CAP and coexisting hypoproteinemia. Hypoproteinemia is a common complication in critically ill patients and can alter the PK of high protein-binding antibacterial agents, thereby impacting both efficacy and safety.[70] For agents with high or moderate protein-binding rates (eg. ceftriaxone, ertapenem), hypoalbuminemia may reduce plasma protein binding and increase free drug concentrations, thereby raising the risk of toxicity.[71] Additionally, hypoproteinemia can affect drug clearance and the volume of distribution. For high-clearance drugs, increased free drug levels may lead to accelerated clearance and reduced efficacy. By contrast, drugs with low clearance and a small volume of distribution may still exhibit plasma concentration fluctuations under conditions of hypoproteinemia.[72] Therefore, antibacterial therapy in patients with hypoproteinemia should be guided by clinical pharmacists and supported by dynamic TDM. Treatment regimens should be adjusted based on serum albumin levels to ensure both efficacy and safety, ultimately improving patient outcomes.

Recommendation 13: When high protein-binding antibacterial agents are used in patients with CAP and coexisting hypoproteinemia, clinical pharmacists should assist emergency physicians in dynamically adjusting the dosage and regimen through TDM to balance efficacy and safety (level II recommendation, level B evidence).

Pregnant and lactating women with CAP. Pregnant women. Antibacterial treatment decisions for pregnant patients with CAP must carefully balance the benefits and risks to both the mother and fetus.[73] In early and mid-pregnancy, β-lactam antibiotics (eg. ceftriaxone) and macrolides (eg. azithromycin) are recommended as first-line options. In severe cases with a risk of *Pseudomonas aeruginosa* infection, anti–pseudomonal β-lactam agents may be considered (eg. ceftazidime).[74] Fluoroquinolones and tetracyclines should be avoided during pregnancy because of their potential teratogenicity and safety concerns. Moreover, the physiological and anatomical changes that occur during pregnancy can significantly alter the PK of drugs. In clinical practice, clinical pharmacists should take into account drug properties, resistance surveillance data, patient allergy history, and placental permeability when assisting emergency physicians in designing and adjusting individualized antibacterial regimens. Enhanced TDM and follow-up on pregnancy outcomes are also essential to ensure the safety of both mother and fetus.

Table 4

Dosage Adjustment of Common Antibacterial Agents in Patients With CAP With Coexisting Hepatic and Renal Impairment

Antibacterial	Elimination Pathway	Dose Adjustment Based on Child-Pugh Classification	Dose Adjustment Based on Creatinine Clearance
β-lactam			
Ceftriaxone	Eliminated *via* kidney and biliary tract	The original dose should be used for mild to moderate hepatic impairment, and the dose should be reduced with caution in severe hepatic disease	Use at original dose
Ceftazidime	Primarily eliminated *via* kidney	Use at original dose	The dosage should be reduced for renal impairment (GFR <50 mL/min)
Ertapenem	Primarily eliminated *via* kidney	Use at original dose	The original dose should be used for mild to moderate renal impairment, and the dose should be reduced with severe renal impairment
Tetracyclines			
Doxycycline	Primarily eliminated *via* kidney	Use with caution in patients with hepatic impairment	Use at original dose
Minocycline	Eliminated *via* kidney and biliary tract	Use with caution in patients with hepatic impairment	Use at original dose*
Omadacycline	Primarily eliminated *via* feces	Use at original dose	Use at original dose
Glycopeptides			
Vancomycin	Primarily eliminated *via* kidney	Use at original dose	Avoid the use of such medications; if their use is clearly indicated, the dosage must be adjusted based on TDM or according to the endogenous creatinine clearance rate of the patient
Macrolides			
Clarithromycin	Primarily eliminated *via* kidney and feces	Use with caution in patients with hepatic impairment	The dosage should be reduced for severe renal impairment
Azithromycin	Eliminated *via* biliary tract	Original dose in patients with mild to moderate hepatic impairment	Use at the original dose for mild and moderate renal impairment; use with caution for severe renal impairment
Quinolones			
Moxifloxacin	Primarily eliminated *via* urine and feces	Use at original dose	Use at original dose
Levofloxacin	Primarily eliminated *via* kidney	Use at original dose	The dosage should be reduced for mild, moderate and severe renal impairment
Nemonoxacin	Primarily eliminated *via* kidney	Use at the original dose for patients with mild and moderate hepatic impairment.	Use at original dose for renal impairment (CLcr≥50 mL/min)
Oxazolidinones			
Linezolid	65% non–renally eliminated	Use at original dose† The dosage should be reduced for severe hepatic impairment	Use at original dose† The dosage should be reduced for moderate and severe renal impairment
Pleuromutilins			
Lefamulin	Primarily non–renally eliminated	Oral administration: Use at the original dose for patients with mild hepatic impairment. No PK data are available for patients with moderate or severe hepatic impairment. Intravenous administration: Use at the original dose for patients with mild or moderate hepatic impairment. The dosage should be reduced for patients with severe renal impairment	Use at original dose

Hepatic impairment is classified as mild, moderate, or severe based on the Child-Pugh score. Renal impairment is classified as mild (60–89 mL/min), moderate (30–59 mL/min), or severe (15–29 mL/min) based on the creatinine clearance.

*For patients with renal impairment, the total daily dose of minocycline should not exceed 200 mg within a 24-hour period. In cases of severe renal impairment, the dosage should be reduced below the standard dose. If long-term treatment is necessary, plasma concentration monitoring is recommended.

†Although the official prescribing information does not recommend dose adjustments of linezolid based on hepatic or renal function, evidence-based studies have indicated that dose reduction may be necessary in elderly patients or those with hepatic and/or renal impairment. Without appropriate adjustment, excessive drug exposure may increase the risk of bone marrow suppression. Therefore, therapeutic drug monitoring is advisable in such population.

CAP, community-acquired pneumonia; CLcr, creatinine clearance; GFR, glomerular filtration rate; TDM, therapeutic drug monitoring.

Lactating women. Lactating women receiving antibacterial therapy are often incorrectly advised to discontinue breastfeeding or stop treatment because of a lack of drug safety data. In reality, most antibacterial agents do not require cessation of breastfeeding or discontinuation of therapy. In clinical practice, emergency physicians should carefully consider the patient's treatment needs, the drug's impact on lactation, the extent of drug excretion into breast milk, and the infant's age to make informed and rational medication decisions. Clinical pharmacists should assess the risk of drug exposure through breast milk based on key drug characteristics (eg. high molecular weight, high protein binding, low apparent volume of distribution). When necessary, clinical pharmacists should also provide guidance on how to temporarily suspend breastfeeding while maintaining lactation and help formulate a plan for safely resuming breastfeeding.

Recommendation 14: Antibacterial treatment decisions for pregnant and lactating women with CAP should balance the benefits and risks to both mother and infant. Clinical pharmacists should assist emergency physicians in making rational treatment decisions, and treatment or breastfeeding should not be discontinued solely due to safety concerns (level II recommendation, level B evidence).

Overall summary

In the antibacterial treatment of emergency patients with CAP, implementing the PPCM model offers valuable professional support in dosage adjustment and TDM. This contributes to individualized medication management and provides a promising approach for the precise treatment of CAP in emergency settings. However, the implementation of the PPCM model in China still faces challenges, including the lack of standardized processes and limited high-quality evidence. It is hoped that the promotion of this guideline will support the development of an emergency pharmaceutical care system and ultimately lead to more standardized, efficient CAP management and improved patient safety.

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Conflict of interest statement

Chuanzhu Lv is an associate editor of *Emergency and Critical Care Medicine* and Xin Li is an editorial board member of *Emergency and Critical Care Medicine*. The article was subject to the journal's standard procedures, with peer review handled independently of this associate editor, this editorial board member, and their research groups. The authors declare no conflict of interest.

Author contributions

Lv C, Zhang G, Ma Y, Gu W, and Guo W contributed to the study design. Gu W, Wang S, Wang L, and Liu Y contributed to the literature review. Gu W, Wang S, Wang L, and Liu Y contributed to the draft of the manuscript. Cao Y, Chen B, Chen X, Chen X, Chen Y, Deng Y, et al. contributed to the revision of the manuscript.

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