

Development of a Pharmacist-Led Multidisciplinary Antimicrobial Stewardship Program at Xieng Khouang Provincial Hospital, Lao People's Democratic Republic

Phaylavone Xaytakounthong¹, Saithip Suttiraksa², Rodchares Nithipaichit³

¹Graduate Student in Master Degree Program (Clinical Pharmacy), Faculty of Pharmacy, Mahasarakham University

²Clinical Trials and Evidence-Based Syntheses Research Unit, Faculty of Pharmacy, Mahasarakham University

³Health Services and Pharmacy Practice Research and Innovation Research Unit,
Faculty of Pharmacy, Mahasarakham University

Abstract

Objective: To develop and evaluate an antimicrobial stewardship program (ASP) led by pharmacists in collaboration with a multidisciplinary team at Xieng Khouang Provincial Hospital, Lao People's Democratic Republic. **Methods:** This study employed a mixed-methods action research design conducted from September to December 2024 in four inpatient wards of Xieng Khouang Provincial Hospital. The study comprised two phases: (1) a qualitative phase to explore the context and problems through in-depth interviews with nine healthcare personnel, and (2) a quantitative phase to develop and evaluate the ASP by comparing the appropriateness of ceftriaxone use among patients diagnosed with infectious diseases before implementation of the program (n=78) and after implementation (n=63). **Results:** The developed ASP was a pharmacist-led system in which pharmacists reviewed the appropriateness of ceftriaxone use according to criteria established based on the hospital context and provided information and consultation to the treatment team to promote rational antibiotic use. After implementation of the ASP, the appropriateness of antibiotic use showed an increasing trend. The proportion of appropriate antibiotic selection in definite therapy increased from 62.5% to 80.0%, although this increase was not statistically significant ($P = 0.856$). The appropriateness of dose and dosing frequency increased significantly from 93.6% to 100.0% ($P = 0.025$). The rate of intravenous-to-oral conversion increased from 84.2% to 87.5%, but this was not statistically significant ($P = 0.733$). The appropriateness of treatment duration increased from 87.1% to 95.2%, but this was not statistically significant ($P = 0.168$). In addition, physicians accepted 90.9% of the pharmacists' recommendations, resulting in a reduction in injectable ceftriaxone use from 368.8 to 181.4 DDDs per 1,000 patient-days, representing a 50.3% decrease. Drug expenditure decreased from 96,161 THB in the pre-implementation period (August) to 46,791 THB in the post-implementation period (December), representing a 51.3% reduction. The average length of hospital stay also decreased from 6.3 days to 5.3 days. **Conclusion:** The developed pharmacist-led ASP for evaluating and advising on antibiotic use in collaboration with a multidisciplinary team tended to improve appropriateness of antibiotic use, reduce antibiotic use and drug costs, and improve clinical outcomes. This approach may serve as a model for further ASP development in hospitals in the Lao People's Democratic Republic.

Keywords: rational use of antibiotics, antimicrobial stewardship program, ceftriaxone, People's Democratic Republic Lao, antimicrobial resistance

Received: Oct 28 2025, **Revised manuscript received:** Mar 31, 2026, **Accepted:** Apr 8, 2026

Correspondence: Rodchares Nithipaichit, Health Services and Pharmacy Practice Research and Innovation Research Unit, Faculty of Pharmacy, Mahasarakham University **E-mail:** rodchares.n@msu.ac.th

การพัฒนาระบบกำกับดูแลการใช้ยาปฏิชีวนะโดยเภสัชกรเป็นแกนนำร่วมกับทีมสหสาขาวิชาชีพ ในโรงพยาบาลจังหวัดเชียงใหม่ สาธารณรัฐประชาธิปไตยประชาชนลาว

ไพลาวอน ไชตาทูลทอง¹, สายทิพย์ สุทธิรักษา², รจเรศ นิธิไพจิตร³

¹นิสิตปริญญาโท หลักสูตรเภสัชศาสตรมหาบัณฑิต สาขาเภสัชกรรมคลินิก คณะเภสัชศาสตร์ มหาวิทยาลัยมหาสารคาม

²หน่วยวิจัยการศึกษาทางคลินิกและการส่งเคราะห์หลักฐานเชิงประจักษ์ คณะเภสัชศาสตร์ มหาวิทยาลัยมหาสารคาม

³หน่วยวิจัยระบบบริการสุขภาพ เภสัชกรรมการปฏิบัติและนวัตกรรม คณะเภสัชศาสตร์ มหาวิทยาลัยมหาสารคาม

บทคัดย่อ

วัตถุประสงค์: เพื่อพัฒนาและประเมินผลระบบกำกับดูแลและส่งเสริมการใช้ยาปฏิชีวนะสมเหตุสมผล (Antimicrobial Stewardship Program: ASP) โดยมีเภสัชกรเป็นแกนนำร่วมกับทีมสหวิชาชีพในโรงพยาบาลจังหวัดเชียงใหม่ สาธารณรัฐประชาธิปไตยประชาชนลาว **วิธีการ:** การศึกษาครั้งนี้เป็นการวิจัยเชิงปฏิบัติการแบบผสมผสานวิธีการ (mixed-method action research) ที่ดำเนินการระหว่างเดือนกันยายน-ธันวาคม พ.ศ. 2567 ในหอผู้ป่วยใน 4 หอของโรงพยาบาลจังหวัดเชียงใหม่ การศึกษาแบ่งเป็น 2 ระยะคือ (1) การศึกษาเชิงคุณภาพเพื่อศึกษาบริบทและสภาพปัญหาโดยการสัมภาษณ์เชิงลึกบุคลากรทางการแพทย์ 9 คน และ (2) การศึกษาเชิงปริมาณเป็นการพัฒนาและประเมินผลระบบ ASP โดยเปรียบเทียบความเหมาะสมการใช้ยา ceftriaxone ในผู้ป่วยที่มีการวินิจฉัยโรคติดเชื้อก่อนพัฒนาระบบ (n = 78) และหลังพัฒนาระบบ (n = 63) **ผลการวิจัย:** ASP ที่พัฒนาขึ้นเป็นระบบที่มีเภสัชกรทำหน้าที่ทบทวนความเหมาะสมของการใช้ยา ceftriaxone ตามเกณฑ์ที่สร้างขึ้นตามบริบทของโรงพยาบาล พร้อมทั้งให้ข้อมูลและคำปรึกษาแก่ทีมผู้รักษา เพื่อส่งเสริมการใช้ยาปฏิชีวนะอย่างสมเหตุสมผล หลังการดำเนินงาน ASP พบว่า ความเหมาะสมในการเลือกยาปฏิชีวนะมีแนวโน้มเพิ่มขึ้น โดยการเลือกใช้ยาหลังทราบผลเพาะเชื้อเพิ่มจากร้อยละ 62.5 เป็น 80.0 แต่ยังไม่เพิ่มขึ้นจนถึงระดับนัยสำคัญทางสถิติ (P = 0.856) ความเหมาะสมของขนาดและความถี่ของการใช้ยาปฏิชีวนะเพิ่มขึ้นอย่างมีนัยสำคัญทางสถิติจากร้อยละ 93.6 เป็น 100.0 (P = 0.025) การบริหารยาจากฉีดเป็นรับประทานเพิ่มจากร้อยละ 84.2 เป็น 87.5 แต่ไม่มีนัยสำคัญทางสถิติ (P = 0.733) และความเหมาะสมของระยะเวลาการใช้ยาเพิ่มขึ้นจากร้อยละ 87.1 เป็น 95.2 แต่ไม่มีนัยสำคัญทางสถิติ (P = 0.168) นอกจากนี้แพทย์ยอมรับข้อเสนอของเภสัชกรร้อยละ 90.9 ส่งผลให้ปริมาณการใช้ยาฉีด ceftriaxone (DDD/1,000 วันนอน) ลดลงจาก 368.8 เป็น 181.4 (ลดลงร้อยละ 50.3) มูลค่าการใช้ยาลดลงจาก 96,161 บาทในช่วงก่อนพัฒนาระบบ (เดือนสิงหาคม) เป็น 46,791 บาทในช่วง หลังพัฒนาระบบ (เดือนธันวาคม) (ลดลงร้อยละ 51.3) และระยะเวลานอนโรงพยาบาลลดลงจาก 6.3 วัน เป็น 5.3 วัน **สรุป:** การพัฒนาระบบ ASP โดยมีเภสัชกรเป็นแกนนำในการประเมินและให้คำปรึกษาด้านการใช้ยาปฏิชีวนะร่วมกับทีมสหวิชาชีพมีแนวโน้มเพิ่มความเหมาะสมในการใช้ยาปฏิชีวนะ ลดปริมาณและค่าใช้จ่ายด้านยาและส่งผลให้ผลลัพธ์ทางคลินิกดีขึ้น จึงสามารถใช้เป็นแนวทางเพื่อพัฒนาระบบ ASP ในโรงพยาบาลของสาธารณรัฐประชาธิปไตยประชาชนลาวต่อไปในอนาคต

คำสำคัญ: การใช้ยาปฏิชีวนะสมเหตุสมผล ระบบกำกับดูแลการใช้ยา เซฟไตรอะโซน สาธารณรัฐประชาธิปไตยประชาชนลาว การดื้อยาด้านจุลชีพ

Introduction

The irrational use of drugs has long been recognized as a major global health problem. It is estimated that fewer than half of patients are treated according to the established standards and more than half use medicines inappropriately. This situation causes adverse drug events, antimicrobial resistance (AMR), and significant waste of health care resources and spending (1). In the United Kingdom, the estimated cost of irrational medicine use in the National Health Service (NHS) is £466 million per year (2). Similarly, US hospitals may incur losses up to US\$5.6 million per year due to drug-related problems (3).

AMR is among the most serious and rapidly growing public health threats, especially for infections caused by multidrug resistant organisms. These pathogens are resistant to two or more classes of antimicrobial agents and in some cases all available antibiotics, making infections difficult or impossible to treat. Six multidrug-resistant pathogens of global concern include *Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Enterobacter spp.* AMR has been identified as a major consequence of inappropriate use of antibiotics (4).

To address this problem, Antimicrobial Stewardship Programs (ASPs) have been widely adopted to promote the appropriate use of antimicrobial agents. ASPs strive to optimize antimicrobial therapy regarding indication, dose, route of administration, and duration of therapy. Successful ASP implementation can improve clinical outcomes, decrease adverse events, minimize unnecessary antimicrobial use, reduce healthcare costs, and contribute to prevention of emergence of AMR (5). The Government of the Lao People's Democratic Republic has developed the National Strategic Plan on AMR 2019–2023 in collaboration between the Ministry of Health and Ministry of Agriculture in response to the growing AMR threat. The plan seeks to decrease the morbidity,

mortality and economic losses due to AMR. The fourth Strategy focuses on the optimization of antimicrobial use in humans and animals and highlights the importance of monitoring of antibiotic utilization at the hospital level (6).

In Lao PDR, a point-prevalence survey in 6,555 inpatient prescriptions showed that ceftriaxone was the most frequently prescribed antimicrobial drug (39.6% of all antibiotics used), followed by metronidazole (17.0%) and gentamicin (10.0%). Pneumonia was the most frequent diagnosis in children ≤ 5 years treated with antimicrobials. Only 26.0% of antimicrobial prescriptions were in accordance with national treatment guidelines. The inappropriate use was especially high in surgical prophylaxis (99.0%). These findings highlight the importance of systematic interventions to improve antimicrobial use (7).

Xiengkhouang Province has a population of 287,683 and is served by one provincial hospital with 100 beds, one military hospital with 150 beds, six district hospitals, 56 health centers, 24 village doctors, and 734 village health volunteers. Hospitals in the province participate in AMR surveillance activities supported by the Fleming Fund Project. The Microbiology Department of Mahosot Hospital serves as the central laboratory for collecting microbiological data and antimicrobial susceptibility data using the WHONET software. In 2021–2022, microbiological data collected from 1702 specimens identified the presence of *S aureus*, *Salmonella spp.*, *E. coli* and *Shigella spp.* In addition, antimicrobial resistant organisms were detected including methicillin resistant *Staphylococcus aureus* or MRSA (18.5%), and extended spectrum beta-lactamase producing organisms or ESBLs (47.3%).

Hospital antibiotic utilization reports from Xiengkhouang Provincial Hospital between 2020 and 2022 demonstrated a continuous increase in ceftriaxone consumption, representing 4.36%, 6.66%, and 8.37% of total antibiotic use, respectively. These findings indicate extensive use of ceftriaxone and suggest that its

consumption exceeds that of many other antimicrobial agents. However, the hospital has not yet established a systematic process for evaluating the appropriateness of ceftriaxone prescribing. Existing monitoring activities are limited to detecting antibiotic consumption without assessing prescribing quality. In addition, increasing antimicrobial expenditures with no data on appropriate antibiotics use throughout medication-use process pose challenges to effective antimicrobial management.

Therefore, the researchers proposed the development of an antimicrobial stewardship-based prescribing evaluation system to systematically identify problems and implement targeted interventions. Ceftriaxone was selected as an initial target of antimicrobial because of its high utilization within the hospital. Once the ASP model for ceftriaxone had been developed and evaluated, it could serve as a framework for expanding antimicrobial stewardship activities to other antibiotics. The objectives of this study were to identify problems related to antimicrobial prescribing evaluation in the hospital and to develop an ASP-based prescribing evaluation model through multidisciplinary team participation.

Methods

Ethical Approval and Study Setting

This study was approved by the Human Research Ethics Committee of Mahasarakham University (Approval No. 385-188/2024). The study was conducted between September and December 2024 at Xiengkhouang Provincial Hospital, Lao People's Democratic Republic. The study was carried out in four inpatient wards, including the internal medicine, infectious diseases, pediatric, and surgical wards. The study consisted of two phases.

Phase 1: Assessment of Context and Problems

Study Design

Phase 1 was a qualitative study conducted in July 2024 before the implementation of the ASP. The

objective of this phase was to explore the context, current antibiotic utilization practices, problems, barriers, and recommendations for ASP development within the hospital.

Key Informants

Nine health professionals involved in antibiotic use evaluation at Xiengkhouang Provincial Hospital. These included one hospital administrator, one internist, one infectious specialist, one pediatrician, one surgeon, three registered nurses, and a member of the Hospital Rational Drug Use Committee. Participants were selected using purposive sampling from those directly involved in antibiotic management. The hospital director was selected as the administrative representative to provide policy-level perspectives.

Data Collection

Data were collected through individual in-depth interviews using a semi-structured interview guide. The interview topics included understanding of rational antibiotic use, current antibiotic utilization practices, existing policies and measures, challenges related to antibiotic use, and recommendations for ASP implementation. Each interview lasted about 15–20 minutes.

To minimize information bias, interviews were conducted individually in a private setting using the same interview guide for all participants. Questions focused on participants' experiences and perspectives regarding antibiotic use practices within the hospital.

Data Analysis

Qualitative data were analyzed using content analysis. Audio recordings were transcribed verbatim and systematically reviewed. Data were interpreted, coded, categorized, and synthesized into key themes and patterns. The findings were used as baseline information for designing and developing the ASP model appropriate to the hospital context.

Phase 2: Development and Evaluation of the ASP

Phase 2 of the study was a quantitative pre–post intervention study conducted to evaluate the impact

of the ASP on the appropriateness of antibiotic use and antibiotic-related outcomes.

Subjects

The subjects consisted of hospitalized patients admitted to Xiengkhouang Provincial Hospital between September and December 2024. Eligible patients were those who received ceftriaxone within 24 hours of admission and were diagnosed with infectious diseases, including pneumonia, urinary tract infection, skin and soft tissue infection, bloodstream infection, or intra-abdominal infection.

Patients were excluded if ceftriaxone was prescribed solely for surgical prophylaxis or if they were discharged within 24 hours after receiving ceftriaxone. This action research included all eligible patients who received ceftriaxone during the specified study periods. Data were collected from all eligible patients during the one-month pre-intervention period (August 2024) and the one-month post-intervention period (December 2024). A total of 78 patients were included before the intervention and 63 patients after the intervention.

Intervention and Data Collection

Prior to ASP implementation, the researcher provided information regarding the study objectives, ASP procedures, and multidisciplinary team roles to hospital personnel. Preparations were made regarding facilities, equipment, and supporting systems. Following ASP implementation, a clinical pharmacist reviewed all inpatient ceftriaxone prescriptions on each working day. Prescription appropriateness was assessed using patient medical records and laboratory data. When an inappropriate antibiotic use was identified, recommendation was given directly to the treating physician through face-to-face discussion and/or documents in the patient's medical record. Pharmacists also monitored antimicrobial susceptibility results and subsequent treatment modifications throughout hospital stay.

The assessment guideline for appropriateness of ceftriaxone use was developed by a multidisciplinary team based on evidence from IBM Micromedex® Drug

Reference and the 52nd edition of the Sanford Guide to Antimicrobial Therapy (2022).

The assessment covered both empirical therapy (before microbiological results were available) and definitive therapy (after susceptibility results became available). Evaluation criteria included 1) appropriate antibiotic selection according to profiles of antimicrobial susceptibility, 2) appropriate dosage and dosing frequency throughout treatment, 3) timely conversion from intravenous to oral therapy when clinical improvement was achieved and 4) appropriate duration of therapy according to treatment guidelines. The assessment guideline was reviewed for content validity by three experts, including an infectious disease specialist, a pediatrician, and an internist.

Antibiotic use was classified as appropriate when all predefined criteria were met. Any deviation from one or more criteria was classified as inappropriate use. To minimize assessment variability, all evaluations were performed by a single investigator.

Outcome Indicators

The primary and secondary outcomes included 1) appropriateness of ceftriaxone use, 2) clinical outcomes, categorized as improved/recovered or treatment failure, based on clinical improvement and discharge status, 3) monthly ceftriaxone consumption in inpatient wards, expressed as Defined Daily Doses (DDD) per 1,000 bed-days, calculated using the following formula: $\frac{\text{Total amount of drug used (in grams)}}{\text{DDD WHO} \times \text{bed-days}}$, 4) ceftriaxone expenditure during the study period, and 5) physician acceptance of pharmacist recommendations regarding antibiotic therapy optimization. All outcome data were obtained from patients' medical records.

Statistical Analysis

Patient characteristics, antibiotic consumption (DDD/1,000 patient-days), antibiotic expenditures, and physician acceptance of pharmacist recommendations were analyzed using descriptive statistics. Comparisons of categorical variables, including appropriateness of antibiotic use and clinical outcomes (improved/

recovered versus treatment failure), between the pre- and post-intervention periods were performed using the Chi-square test or Fisher's exact test, as appropriate. Length of hospital stay, a non-normally distributed continuous variable, was compared using the Mann-Whitney U test. Statistical significance was set at $P < 0.05$. Data were analyzed using Stata version 14.

Results

Phase 1: Context and Problem Assessment

Interviews were conducted with nine health workers from Xiengkhouang Provincial Hospital. The mean age of the participants was 42 years (range 34–50 years) and the mean length of professional experience was 16 years. The majority of the participants were physicians ($n=6$) and the rest were registered nurses ($n=3$). Most were medical specialists ($n = 6$). Two participants had bachelor's degrees and one a master's degree. Two main themes about problems in assessing the appropriateness of antibiotic prescribing were found in the interviews.

Antibiotic Prescribing Situation

Most participants indicated that the use of antibiotics in the hospital had increased over time. Inappropriate antibiotic use was contributed by antibiotics prescribing without clear clinical indications, patient demands of antibiotics especially among those presenting with fever or upper respiratory tract infections and seasonal infectious diseases. Antibiotic use reportedly increases during rainy and cold seasons and during outbreaks of infectious diseases in the region.

Systems for ASP and Policies

The hospital had a number of policies and systems in place to promote rational drug use including: 1) a policy to encourage microbiological testing prior to the initiation of antibiotic therapy; 2) a Rational Drug Use (RDU) Committee responsible for monitoring medication use across the hospital including antibiotics; and 3) a partnership with the Lao-Oxford-Mahosot Hospital-

Wellcome Trust Research Unit (LOMWRU) to promote microbiological surveillance and develop antibiograms.

Several important limitations were identified despite these measures. This included inconsistent compliance with the policy of obtaining microbiological testing before starting antibiotics, the absence of interdepartmental information sharing systems, no adjustment of antibiotic therapy based on antimicrobial susceptibility results, and inappropriate treatment duration in many instances.

In conclusion, the results showed that inappropriate antibiotic prescribing was correlated with several system-level problems, such as prescribing practices that were inconsistent with hospital treatment guidelines and international standards, failure to obtain microbiological testing before initiating treatment, failure to adjust therapy based on microbiological and susceptibility results, and inappropriate treatment duration throughout the whole therapeutic process. These results highlighted the importance of an ASP for promoting rational antibiotic use and better treatment outcomes.

Phase 2: Development and Implementation of ASP

The ASP developed in the study was implemented via multidisciplinary collaboration at Xiengkhouang Provincial Hospital. The program was run by the hospital's Rational Drug Use Committee. This Committee existed prior to the study and was made up of physicians, pharmacists and nurses.

The ASP was developed in 3 meetings with multidisciplinary teams. The first meeting was held to present the results of Phase 1, and identifying existing problems. The second meeting was aimed at developing guidelines for ceftriaxone prescribing. The third meeting defined the roles and responsibilities of each professional group and established operational procedures for ASP implementation.

Once in place, pharmacists were tasked with reviewing inpatient antibiotic prescriptions daily against

patient medical records. They also informed physicians when inappropriate use of antibiotics was noted and communicated directly with prescribers. Pharmacists also reviewed microbiological results, and followed up treatment changes to ensure guideline compliance. ASP implementation consisted of the following components:

1) Patient screening: On each working day, pharmacists screened antibiotic prescriptions for all hospitalized patients with special attention to patients who received ceftriaxone within the first 24 hours of admission.

2) Appropriateness assessment: Pharmacists evaluated the appropriateness of the ceftriaxone use according to the data collected from the medical records, which included diagnosis, clinical presentation, laboratory results, and microbiological results. The evaluation was performed according to the pre-defined criteria (Tables 1–4 in appendix), which included antibiotic selection, dosage and dosing interval, transition from intravenous to oral therapy, and length of therapy.

3) Pharmacist recommendations: When the pharmacists identified inappropriate use of antibiotics,

they recommended dose adjustment, antibiotic substitution, discontinuation of therapy or modification based on microbiological results and susceptibility data to the treating physicians. Recommendations were verbal and/or documented in the patient's medical record.

4) Follow-up monitoring: Patients were closely monitored for treatment response, microbiological results, and any necessary treatment modifications to ensure compliance with ASP guidelines.

5) IV to oral conversion: Patients were switched from IV to oral therapy when they met the predetermined criteria including clinical improvement, afebrile status, and ability to tolerate oral medications.

6) Documentation and evaluation: Pharmacist recommendations and physician acceptance were documented and later used to evaluate ASP outcomes.

Patient Characteristics

A total of 78 patients were included during the pre-intervention period and 63 patients during the post-intervention period. The baseline characteristics of the patients are presented in Table 1. There were no

Table 1. Patient characteristics before and after implementation of the Antimicrobial Stewardship Program (ASP)

characteristics	before ASP Implementation (August 2024)	after ASP Implementation (December 2024)	P
number of patients	78	63	
sex, n (%)			0.989 ¹
male	48 (61.6)	39 (61.9)	
female	30 (38.4)	24 (38.1)	
age (years), mean ± SD	26.9 ± 25.8	27.35 ± 26.56	0.920 ²
underlying diseases, n (%)			0.097 ³
none	75 (96.1)	59 (93.7)	
present	3 (3.9)	4 (6.3)	
hypertension	1 (33.3)	0 (0.0)	
diabetes mellitus	0 (0.0)	4 (100.0)	
other diseases*	2 (66.7)	0 (0.0)	

Note: *Patients may have had multiple underlying diseases

1: chi-square test; 2: independent sample t-test; 3: Fisher's Exact test

Table 2. Appropriateness of antibiotic use before and after ASP implementation

appropriateness measure	before ASP implementation ¹ (August 2024)	after ASP implementation ¹ (December 2024)	P ²
number of patients	78	63	
definitive antibiotic selection	5/8 (62.5)	8/10 (80.0)	0.856
intravenous-to-oral (IV-to-PO) conversion	32/38 (84.2)	21/24 (87.5)	0.733
dose and dosing frequency	73/78 (93.6)	63/63 (100.0)	0.025
duration of therapy	68/78 (87.1)	60/63 (95.2)	0.168

1: Analyses were performed only among patients eligible for each appropriateness measure. For example, definitive antibiotic selection was evaluated only in patients with available antimicrobial susceptibility results (pre-intervention, n = 8; post-intervention, n = 10). Data are presented as n/N (%), where n is the number of patients assessed as appropriate and N is the total number of patients evaluated. 2: Fisher's exact test.

statistically significant differences between the two groups regarding sex, age, or underlying diseases ($P > 0.05$). Male patients constituted the majority in both groups, accounting for 61.6% of patients in the pre-intervention period and 61.9% in the post-intervention period. The mean age was comparable between the two groups (26.9 ± 25.8 years and 27.4 ± 26.6 years, respectively). Most patients were aged 0–20 years, representing 48.7% and 47.6% of the pre- and post-intervention groups, respectively. The majority of patients had no underlying diseases, accounting for 96.1% of patients before ASP implementation and 93.7% after implementation.

Appropriateness of Antibiotic Use

Table 2 presents the results of the assessment of antibiotic-use appropriateness before and after implementation of the ASP. Appropriateness of antibiotic selection following receipt of microbiological testing and susceptibility results showed an increasing trend after ASP implementation. The proportion of appropriate antibiotic selection increased from 62.5% during the pre-intervention period to 80.0% during the post-intervention period. However, this difference was not statistically significant ($P = 0.856$).

The appropriateness of intravenous-to-oral conversion improved from 84.2% to 87.5% after ASP

implementation. However, the difference was not statistically significant ($P = 0.733$). The appropriateness of dose and dosing frequency improved significantly, increasing from 93.6% before implementation to 100.0% after implementation ($P = 0.025$). The appropriateness of antibiotic duration also increased from 87.1% to 95.2% after ASP implementation, although this difference was not statistically significant ($P = 0.168$).

Acceptance of Pharmacists' Recommendations

Physician acceptance of pharmacists' recommendations was evaluated during September–December 2024. During this period, 22 instances of antibiotic use inconsistent with the established prescribing guidelines were identified. Pharmacists provided recommendations to physicians in these instances. Physicians accepted 6 recommendations regarding antibiotic selection after antimicrobial susceptibility results were available, from the total 8 suggested by pharmacists. Physicians accepted all recommendations related to dose and dosing frequency (6 cases), intravenous-to-oral conversion (4 cases), and inappropriate duration of therapy (4 cases). Overall, physicians accepted 20 of 22 recommendations of the pharmacists (90.9%), while the remaining 2 recommendations (9.1%) were not accepted and the original therapy was continued. It should be noted that

this assessment was conducted only during the 4-month intervention period (September–December 2024), and therefore the number of inappropriate antibiotic use may differ from the overall appropriateness analysis reported in other parts of the study.

Clinical Outcomes

In the pre-intervention group, 76 patients (97.4%) showed clinical improvement, while 2 patients (2.6%) experienced treatment failure. In the post-intervention, all patients showed clinical improvement. However, the difference between the two periods was not statistically significant ($P = 0.498$).

Antibiotic Consumption and Cost

The consumption of ceftriaxone before ASP implementation (August 2024) was 3,915 vials, whereas consumption after the ASP implementation (December 2024) decreased to 1,905 vials. When expressed as DDD per 1,000 patient-days, ceftriaxone use decreased from 368.8 to 181.4 DDD/1,000 patient-days, indicating a reduction in antibiotic consumption following ASP implementation.

Monthly expenditure on ceftriaxone was 96,161 THB in August 2024 (before ASP implementation). After ASP implementation, the monthly cost decreased to 46,791 THB in December 2024.

Discussion

Qualitative findings revealed that most of the healthcare professionals had a good understanding of the principles of rational antibiotic use. However, limitations in the healthcare system persisted, including failure to collect microbiological specimens before antibiotic therapy, no modification of antibiotics according to antimicrobial susceptibility results, and no systematic monitoring of antibiotic use. These problems were crucial barriers to adherence to standard treatment guidelines.

One of the major problems encountered in the qualitative phase before the developed system was implemented was the inaccessibility to microbiological tests before starting antibiotics. However, results of Phase 2 revealed that the developed ASP could not fully solve this problem. This could be attributed to laboratory capacity limitations, delays in reporting microbiological results, and physicians' prescribing behaviors and decision-making practices. These systemic factors require long-term and ongoing improvements.

Appropriate antibiotic prescribing in hospitals requires the development of a well-structured ASP, integration of multidisciplinary teamwork, use of microbiological data and continuous monitoring of antibiotic use. These findings are in keeping with international evidence that strong implementation of ASP can decrease unnecessary use of antibiotics, minimize AMR and reduce treatment costs (8, 9). This study showed that implementation of the ASP improved one aspect of antibiotic appropriateness, dose and dosing frequency, which increased from 93.6% to 100.0%. Improvements were also noted in the appropriateness of definitive antibiotic selection, the switch from IV to oral therapy and duration of therapy, but these changes did not reach statistical significance.

ASP Implementation improved appropriateness of antibiotics selection based on microbiological and susceptibility profiles, from 62.5% before intervention to 80.0% after intervention, but with no statistical significance. These results are in accordance with the results from the study of Prakongsai et al. (10), which showed that pharmacist intervention improved the appropriateness of antibiotic use following availability of susceptibility profiles from 57.6% to 74.4% ($P=0.16$). This trend underscores important role that pharmacists play in promoting rational antibiotic use. The lack of statistical significance in this study may cause by the small sample size or the short period of follow-up.

After implementation of the developed system the appropriateness of dose and dosing frequency

significantly increased from 93.6% to 100.0%. Pharmacists played an important role by reviewing prescriptions and making recommendations to physicians whenever inappropriate prescribing was identified. These findings are consistent with the study by Jittawadee Kamonphut (11) that concluded that ward pharmacists' concurrent assessment could detect drug related problems and improve prescribing patterns, especially in patients with impaired renal function. This supports effectiveness of multidisciplinary collaboration in improving prescribing behaviors.

The rate of appropriate conversion from IV to oral therapy increased from 84.2% to 87.5%. The difference was not statistically significant, but the result is suggestive of a trend towards more appropriate antibiotic use. This finding is consistent with the study by Park et al. (12) who found that ASP led to significant decreases in hospital length of stay and associated costs ($P < 0.05$). Similarly, the appropriateness of treatment duration increased from 87.1% to 95.2%. This trend is not statistically significant, but it reflects the reduction of unnecessary prolonged antibiotic use. The results on improvement of appropriateness of treatment duration after pharmacist involvement have been reported by Prakongsai et al. (10) and Ananwatthanakit (13). Together these findings support the important role of pharmacists in antimicrobial stewardship.

Following the ASP implementation, 90.9% of pharmacists' recommendations were accepted by physicians. All pharmacist recommendations on dose and dosing frequency were accepted and resulted in a prescription change. These results are in line with those reported in the studies by Kerdasak (14) and Kamonphut regarding of high physicians' acceptance rate of pharmacists' recommendations (11). However, overall appropriateness of antibiotics use did not reach 100%, even though the acceptance rate was high. Appropriateness assessment reflects the entire treatment process, whereas the acceptance rate in the study was calculated only in the cases with pharmacist

intervention. In addition, some patients may have had clinical complexity that precluded full adherence with the guideline.

After ASP implementation, the percentage of patients with clinical improvement increased from 97.4% to 100.0% and no treatment failures occurred. The improved clinical outcome suggests beneficial effects of multidisciplinary care under the ASP, although the difference was not statistically significant. However, these results are not consistent with the results of Ananwatthanakit (13), who reported a statistically significant improvement in favorable clinical outcomes from 72.1% to 81.6%. Differences between studies may be related to patient populations, disease severity, infection types, and ASP implementation models.

After implementation of the ASP, ceftriaxone consumption declined from 368.8 to 181.4 DDD/1,000 patient-days, reflecting a substantial decrease in antibiotic use and better prescribing practices. This finding is in line with the result of the study by Apisamthanarak et al. (15) that the implementation of antibiotic control measures together with educational interventions could reduce antibiotic prescribing from 640 to 400 prescriptions per 1,000 patient-days.

Antibiotic expenditure decreased from 96,161 THB to 46,791 THB which was in accordance with the reduction of antibiotic use after ASP implementation. These findings are in line with the study of Pimpha (16) which compared outcomes and drug costs associated with IV-to-oral antibiotic conversion and found significantly lower drug costs in the conversion group compared to the non-conversion group. This suggests that a switch from IV to oral therapy is a good strategy to reduce medication costs.

This study only considered direct drug costs excluding indirect costs such as intravenous fluids, medical supplies or personnel costs. However, the results are still indicative of the potential of ASP to reduce drug expenditure. ASP has been shown to consistently reduce antibiotic consumption and related

costs. Therefore, conversion from IV to oral therapy is a cost-effective and safe strategy that does not compromise clinical outcomes, but reduces injection-related complications, and hospital-acquired infections, nursing workload, and increases patient comfort.

There are several limitations in the study. Firstly, data collection before and after implementation of ASP was conducted in different seasons (rainy and winter), which might have influenced infection patterns and antibiotic prescribing. Second, the lack of a control group in the pre-post study also limits the ability to isolate the effect of ASP from confounding factors such as pathogen type, disease severity, or changes in clinical management. Third, the relatively short duration of the study (4 months) and the small sample size increased the risk of type II error, i.e., true differences may not have been statistically significant. Finally, this study may have been affected by the Hawthorne effect, in which healthcare personnel being observed may temporarily change their prescribing behavior.

Recommendations

Hospitals need to develop context-specific strategies to promote rational use of antibiotics through active, multidisciplinary collaboration. Additional work is needed to identify barriers to obtaining microbiological and susceptibility testing to inform an appropriate treatment. Furthermore, additional studies should expand to other settings other than hospital and should assess strategies to promote rational use of antibiotics among patients who are receiving antibiotics before hospital admission.

Conclusion

Implementation of the ASP at Xiangkhouang Provincial Hospital demonstrated that ASP led by a pharmacist with the support of a multidisciplinary team can improve appropriateness of antibiotic use, decrease antibiotic use and costs, and facilitate better clinical outcomes. This model can be a practical framework for ASP development in hospitals of Lao PDR. Policy

makers should encourage continuous training of staff, formulation of treatment guidelines and expansion of the role of clinical pharmacists.

Acknowledgements

The authors would like to express sincere gratitude to Dr. Viladeth Praphasiri, the hospital administrators, healthcare professionals, nurses, and laboratory staff of Xiangkhouang Provincial Hospital for their valuable cooperation in data collection. The authors also thank Xiangkhouang Provincial Hospital, Kantonsspital Winterthur, and the Faculty of Pharmacy, Mahasarakham University for financial and research support.

Use of Artificial Intelligence in Manuscript

The authors acknowledge the assistance of GPT-5.2 for language refinement, grammar correction, and improved clarity of academic writing. All authors contributed to the study conception and design. All authors read and approved the final manuscript. The authors confirm that they have independently reviewed, revised and verified all data, content and research findings presented in this manuscript and take full responsibility for the accuracy, originality and integrity of the final manuscript.

References

1. World Health Organization. The pursuit of responsible use of medicines: sharing and learning from country experiences [online]. 2012 [cited May 6, 2025]. Available from: apps.who.int/iris/handle/10665/75828
2. Public Health England. Health matters: antimicrobial resistance (AMR) [online]. 2017 [cited May 6, 2025]. Available from: www.gov.uk/government/publications/health-matters-antimicrobial-resistance
3. Centers for Disease Control and Prevention. Antibiotic resistance threats in the United States, 2019 [online]. 2019 [cited May 6, 2025]. Available

- from: www.cdc.gov/drugresistance/pdf/threats-report/2019-ar-threats-report-508.pdf
4. World Health Organization. Antimicrobial resistance: global report on surveillance 2014 [online]. 2014 [cited May 6, 2025]. Available from: apps.who.int/iris/handle/10665/112642
 5. Barlam TF, Cosgrove SE, Abbo LM, MacDougall C, Schuetz AN, Septimus EJ, et al. Implementing an antibiotic stewardship program: guidelines by the Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America. *Clin Infect Dis*. 2016; 62: e51–e77.
 6. Ministry of Health (Lao PDR), Ministry of Agriculture and Forestry (Lao PDR). National strategic plan on antimicrobial resistance 2019–2023 [online]. 2019 [cited May 6, 2025]. Available from: <https://moh.gov.la>
 7. Chansamouth V, Chommanam D, Roberts T, Keomany S, Paphasiri V, Phamisith C, et al. Evaluation of trends in hospital antimicrobial use in the Lao PDR using repeated point-prevalence surveys-evidence to improve treatment guideline use. *Lancet Reg Health West Pac*. 2022; 27:100531. doi: 10.1016/j.lanwpc.2022.100531.
 8. Schuts EC, Hulscher MEJL, Mouton JW, Verduin CM, Stuart JWTC, Overdiek HWPM, et al. Current evidence on hospital antimicrobial stewardship objectives: a systematic review and meta-analysis. *Lancet Infect Dis*. 2016; 16: 847–56.
 9. World Health Organization. Antimicrobial stewardship : a practical guide [online]. 2019 [cited May 6, 2025]. Available from: apps.who.int/iris/handle/10665/329404
 10. Prakongsai N, Siriphongphan C, Ruangdej K, Namsiriphongphan W. Effectiveness of drug utilization evaluation on Piperacillin-Tazobactam use at Prapokklao Hospital. *Journal of Prapokklao Hospital Clinical Medical Education Center* 2013; 30: 6–23.
 11. Kamolput J. Drug utilization evaluation of cefoperazone/sulbactam in a community hospital in Kalasin Province. *Thai Journal of Pharmacy Practice*. 2016; 8: 149–55.
 12. Park SM, Kim HS, Jeong YM, Lee JH, Lee E, Song KH, et al. Impact of intervention by an antimicrobial stewardship team on conversion from intravenous to oral fluoroquinolones. *Infect Chemother*. 2017; 49: 31–7.
 13. Ananwattanakit M, Usayaporn S, Tandawichien T, Puthilepong C, Pengsupap T. Effect of pharmacist participation in antimicrobial stewardship program on appropriateness of antibiotic use. *Thai Pharmaceutical and Health Science Journal* 2015; 10: 1–9.
 14. Kerdsak Na Waengnoi T. Drug use evaluation antimicrobials in inpatient department, Phukhieo Chalermprakit Hospital, Chaiyaphum Province. *Chaiyaphum Medical Journal* 2021; 41: 68–77.
 15. Apisarnthanarak A, Danchaivijitr S, Khawcharoenporn T, Limsrivilai J, Warachan B, Bailey TC, Fraser VJ. Effectiveness of education and an antibiotic-control program in a tertiary care hospital in Thailand. *Clin Infect Dis*. 2006; 42: 768–75.
 16. Phimpha P. The comparison of outcomes and drug costs on conversion from intravenous to oral administration in patients with community-acquired pneumonia. *Nongkhai Hospital Journal*. 2010; 21: 1–8.

Appendix

Criteria for assessing appropriateness of antibiotic use

The researcher, in collaboration with a multidisciplinary team, developed criteria for assessing the appropriateness of antibiotic use based on evidence from IBM Micromedex® Drug Reference and The Sanford Guide to Antimicrobial Therapy 2022 (52nd edition). The appropriateness of antibiotic use was evaluated based on four main components:

1. Drug selection: consistency with the indication, treatment guidelines, and microbiological and susceptibility profiles.
2. Dosage regimen: appropriateness of dose according to body weight and patient clinical condition.

3. IV-to-oral switch: consideration for switching from intravenous to oral antibiotics when the patient had been afebrile for ≥ 24 –48 hours, showed clinical improvement, and was able to tolerate oral medications.

4. Duration of therapy: consistency with standard treatment guidelines for each disease.

Antibiotic use not meeting any of these criteria was classified as “inappropriate antibiotic use.”

Table 1. Criteria for appropriate antibiotic selection

infectious disease	empiric therapy	common causative pathogens	recommendations following microbiological findings
Pneumonia	ceftriaxone	<i>Streptococcus pneumoniae</i> , <i>Haemophilus influenzae</i> , <i>Moraxella catarrhalis</i> and atypical pathogens	Adjust antibiotics according to susceptibility results; for example, use carbapenems for ESBL-producing organisms and vancomycin for MRSA
Urinary tract infection	ceftriaxone	<i>Escherichia coli</i> , <i>Klebsiella spp.</i> , <i>Proteus spp.</i> , <i>Enterococcus spp</i>	Use carbapenems for ESBL-producing organisms or adjust treatment according to antimicrobial susceptibility results.
Skin and soft tissue infection	ceftriaxone	<i>Staphylococcus aureus</i> , <i>Streptococcus spp.</i>	Use vancomycin or other appropriate agents for MRSA
Bloodstream infection	ceftriaxone	Extended spectrum beta-lactamase (ESBL), Methicillin-resistant <i>Staphylococcus aureus</i> (MRSA)	Adjust treatment according to microbiological and susceptibility profiles
Intra-abdominal infection	ceftriaxone + metronidazole	<i>Enterobacteriaceae</i> and anaerobes	Use carbapenems in severe cases or for ESBL-producing organisms
Bone and joint infection	ceftriaxone	<i>Staphylococcus aureus</i> , <i>Streptococcus spp.</i>	Use vancomycin for MRSA and adjust treatment according to microbiological and susceptibility profiles

Note: The selection of antibiotics was determined based on disease severity, patient risk factors, and antimicrobial susceptibility test results.

Table 2. Dosage of intravenous antibiotics

drug name	adult dose	pediatric dose	notes
ceftriaxone	1–2 g IV every 24 hours	50–75 mg/kg/day IV or IM	Adjust according to disease severity
meropenem	1 g IV every 8 hours	10–15 mg/kg every 8 hours	Used for drug-resistant infections (e.g., ESBL-producing organisms)
vancomycin	15–20 mg/kg every 8–12 hours	10–15 mg/kg every 6–8 hours	Adjust according to renal function and serum drug levels

Table 3. Intravenous-to-oral antibiotic switch criteria

infectious disease	intravenous antibiotic	oral antibiotic
pneumonia	ceftriaxone	ciprofloxacin Adults: 500-750mg before meals every 12 hours Children: 10-20mg/kg divided every 12 hours
		doxycycline Adults: 100mg every 12 hours Children: 2-4mg/kg divided every 12 hours
		amoxicillin Adults: 500-1000 mg every 8 hours Children: 90mg/kg/day divided every 12 hours
		amoxicillin/clavulanic acid Adults: 875/125 mg every 12 hours Children: 20-40mg/kg/day divided every 12 hours
urinary tract infection	ceftriaxone	Norfloxacin adults: 400 mg before meals every 12 hours
		ofloxacin adults: 200-400 mg before meals every 12 hours children:10-15mg/kg divided every 12 hours
		ciprofloxacin adults: 250-500 mg before meals every 12 hours children: 10-20mg/kg divided every 12 hours
		cephalexin adults: 500 mg every 8-12 hours children:50-100mg/kg divided every 6 hours
		amoxicillin adults: 500-1000 mg every 8 hours children: 90mg/kg/day divided every 8 hours
		sulfamethoxazole/trimethoprim adults: SMX800/TMP160 mg twice daily children: 8 mg/kg divided every 12 h (calculated based on TMP)
skin and soft tissue infection	ceftriaxone	amoxicillin/ clavulanic acid adults: 875/125 mg every 12 hours children: 20-40mg/kg/day divided every 12 hours
		ciprofloxacin (for gram-negative bacteria only) adults: 500-750 mg before meals every 12 hours children: 10-20mg/kg divided every 12 hours
		sulfamethoxazole/ trimethoprim adults: SMX800-1600 mg/TMP160-320 mg twice daily children: 8mg/kg divided every 12 hours (calculated based on TMP)

Table 3. Intravenous-to-Oral Antibiotic Switch (continued)

infectious disease	intravenous antibiotic	oral antibiotic
bloodstream infection	ceftriaxone	consider oral switch only in clinically stable patients
		cephalexin
		adults: 500-1000 mg every 6-8 hours
		children: 25-50 mg/kg/day divided every 8 hours
		amoxicillin
		adults: 500-1000 mg every 8 hours
		children: 90mg/kg/day divided every 8 hours
		amoxicillin/clavulanic acid
		adults: 875/125 mg every 12 hours
		children: 20-40mg/kg/day divided every 12 hours
intra-abdominal infection	ceftriaxone + metronidazole	amoxicillin/ clavulanic acid
		adults: 875/125 mg every 12 hours
		children: 20-40mg/kg/day divided every 12 hours
		ciprofloxacin (if anaerobic coverage is not required)
		adults: 500 mg before meals every 12 hours
		children: 10-20mg/kg divided every 12 hours
bone and joint infection	ceftriaxone	amoxicillin/ clavulanic acid
		adults: 875/125 mg every 12 hours
		children: 20-40mg/kg/day divided every 12 hours

Note: Antibiotic selection for IV-to-oral switch should be based on pathogen susceptibility and drug bioavailability.

Table 4. Duration of treatment for infectious diseases

infectious disease	duration of treatment	criteria for clinical improvement
pneumonia	5–7 days	afebrile and improvement in respiratory symptoms
urinary tract infection	3–14 days	improvement in urinary symptoms and no fever
skin and soft tissue infection	3–14 days	reduction in swelling, redness, and pain
bloodstream infection	7–14 days	afebrile and stable vital signs
intra-abdominal infection	4–7 days	reduction in abdominal pain after source control
bone and joint infection	at least 4–6 weeks	reduction in pain and inflammation

Note: Duration of treatment should be adjusted based on clinical response and disease severity.