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ORIGINAL RESEARCH

Application of Lean Six Sigma Combined with Pre-Prescription Review System in Reducing the Irrational Rate of Emergency Prescriptions: A Single Center Study

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Purpose: To explore the application of Lean Six Sigma (LSS) combined with pre-prescription review system in reducing the irrational rate of emergency prescriptions.

Methods: The emergency prescriptions of our hospital in May 2022 to May 2023 and June 2023 to December 2024 were selected as the research objects. Based on the pre-prescription review system and LSS, a comparative analysis was carried out regarding the irrational rate of emergency prescriptions, the changing trend of the irrational rate, the types of irrational prescriptions and their departmental distribution, patients' satisfaction, and the proportion of doctors' returning and modifying irrational prescriptions before and after the implementation of intervention measures.

Results: After the adoption of LSS and Review system, the irrational rate of emergency prescriptions was significantly reduced ($P<0.001$); The irrational prescription rate decreased by 0.07% ($P<0.001$, 95% CI=[−0.06, 0.20]) month by month; The main types of irrational prescriptions remained unchanged, but except for combination medication, incompatibility and repeated medication, all types of irrational prescriptions were significantly lower than those before the intervention ($P<0.05$); Before and after the intervention, the irrational prescriptions were mainly issued by emergency internal medicine and urology emergency department, and the pediatric emergency department increased after the intervention; Patients' satisfaction was significantly improved after intervention ($P<0.05$); The proportion of physicians returning to correct irrational prescriptions increased significantly after the intervention ($P<0.001$).

Conclusion: LSS combined with pre-prescription review system can effectively reduce the irrational rate of emergency prescriptions, optimize emergency medication management, and ensure patient medication safety.

Keywords: Lean Six Sigma, pre-prescription review system, emergency, irrational prescriptions

Introduction

Emergency patients are characterized by sudden onset, severity, and rapid changes in condition. Emergency doctors must formulate safe and effective drug treatment plans for patients with acute diseases under high-pressure and fast-paced working conditions. Due to the frequent involvement in the rapid treatment of critically ill patients, the risk of medication errors in the emergency department is relatively high.[1] The incomplete information of emergency patients, the combined use of multiple drugs, sudden changes in condition, and frequent use of high-risk drugs all directly affect the medication safety of patients.[2] It has been reported that approximately 3% of hospital-related adverse events occur in the emergency department.[3] Another study shows about 0.63 medication errors per hour in the emergency department, mainly involving inappropriate dosage, missed dosing, and incorrect dosing frequency.[4] Among them, 47.8% of medication errors may cause harm to patients and even threaten their lives. It is evident that the quality of emergency prescriptions directly affects patients' treatment outcomes and medication safety. The existence of irrational prescriptions in the emergency

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department delays the treatment and increases medical risks and resource waste. Therefore, strengthening the management of emergency prescriptions is of great significance.

The "Medical Institution Prescription Review Standards" released on July 10, 2018, clearly states that "all prescriptions must be reviewed and approved before entering the pricing and charging and dispensing stages".[5] Medical institutions should establish prescription review centers and dedicated review pharmacist teams. The overall review quality can be improved through the informatization of the review center platform and the homogenization of pharmacists, thereby enhancing the safety and rationality of the entire medical service system. Tianjin First Central Hospital (hereinafter "our hospital") launched the pre-prescription review system in April 2019. Clinical pharmacists and information pharmacists continuously optimized the review system and our hospital's physician workstations and information center. They maintained the drug rule database in a personalized manner, achieving multi-dimensional continuous optimization. In April 2022, the pre-prescription review system was fully implemented in the outpatient and emergency departments, gradually realizing the review of all prescriptions before patient payment. An efficient review system can effectively intercept irrational prescriptions and improve the rationality of prescriptions to a certain extent. However, relying solely on information technology makes it difficult to solve systemic problems comprehensively. Through the analysis of intercepted prescriptions in the background, many areas for improvement have still been identified.

Lean theory is a continuous and long-term value assessment system that optimizes processes and eliminates non-value -added activities.[6] Six Sigma is a management model centered on data and driven by improving patient satisfaction, which continuously pursues improvement.[7] In brief, Lean places its emphasis on the elimination of waste and the reduction of speed, thereby enhancing process efficiency and diminishing overall costs, with a specific focus on customer satisfaction. It offers a set of tools and techniques intended to minimize lead times, inventories, setup times, rework, and other latent inefficiencies within the factory. Conversely, Six Sigma endeavors to decrease variations and defects via statistical analysis and rigorous problem-solving tools. It is a project-oriented, statistically-based methodology that furnishes data to drive solutions. Therefore, each approach presents a distinct set of tools, and their integration can maximize the potential that either approach could attain independently.[8] Lean Six Sigma (LSS) is a new management approach that combines lean thinking and Six Sigma management, earliest used in the manufacturing sector.[9] But today it's used in the public sector, in customer service, in healthcare and can be used everywhere.[10] It was first applied to the healthcare system in the late 1990s, and hospital pharmacies are integral to the healthcare system.[11] The implementation of LSS in hospital pharmacy operations has demonstrated substantial impacts. It has brought about a reduction in the turnaround time of medication,[12] an improvement in process efficiency,[13] and an enhancement of inventory management.[14] Moreover, it has led to a decrease in medication errors,[15] an increase in satisfaction levels,[16] cost savings,[17] an improvement in prescription accuracy,[18] and an augmentation of knowledge.[19]

DMAIC, as its basic implementation model, mainly includes five basic steps: define, measure, analyze, improve, and control. The LSS strategy under the roadmap of DMAIC ensures a robust framework, especially for service-quality improvement. LSS utilizes the tools and techniques from both Lean and Six Sigma to optimize resource consumption and increase the speed and accuracy of the process simultaneously.[20] Based on the pre-prescription review, this study adopted LSS as an intervention measure. It collected information regarding irrational prescriptions in the emergency department of our hospital both before and after the intervention, compared the data relevant to medication use before and after the intervention, evaluated the intervention effect, and put forward targeted improvement strategies. The aim was to guarantee the safety, rationality, and effectiveness of patients' medication use and also to offer a reference for other hospitals to enhance the rationality of prescriptions.

Materials and Methods

Data Sources

All emergency prescriptions in our hospital are reviewed via a pre-approval system founded on personalized rule libraries. These libraries rely on evidence-based medical references, including drug instructions and guidelines, and are also integrated with relevant policies, laws, and regulations. The system conducts pharmacological interventions on

irrational prescriptions and records them. Pharmacists summarize and analyze the results. The irrational emergency prescriptions recorded by the system from May 2022 to May 2023 are regarded as the pre-intervention period, and those from June 2023 to December 2024 are regarded as the post-intervention period.

DMAIC Management

Using the DMAIC model, it is carried out according to the five steps of define, measure, analyze, improve, and control. The work content is shown in Figure 1.

Define: This phase provides the foundation for the whole project by ensuring all team members know what must be done and how to do it. This phase primarily focusses on clearly identifying and characterising the problem or opportunity for improvement.[21] Our hospital is equipped with 16 emergency departments, and the daily volume of emergency prescriptions is approximately 1500. Among them, prescriptions from the emergency internal medicine department account for over 60% of all emergency prescriptions. This equates to an average of about 40 prescriptions per person per hour. The workload is substantial, and the occurrence of irrational prescriptions is prone to happen. The National Health Commission has incorporated the rate of irrational prescriptions into the performance appraisal system of

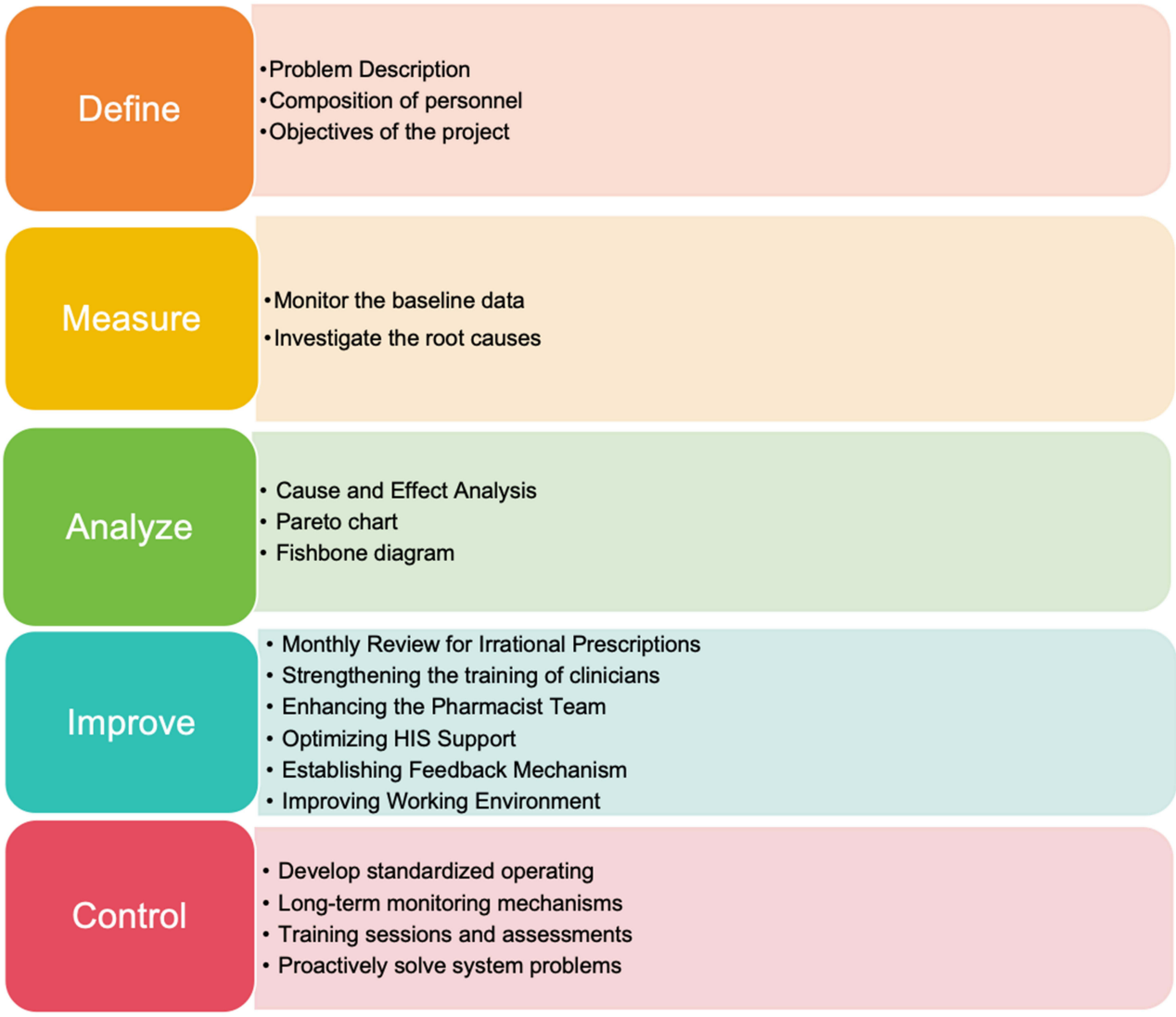

Figure 1 Work content diagram of DMAIC.

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hospitals as an improvement target. This is an inevitable measure to meet the regulatory requirements of the industry and an active choice for medical institutions to enhance their internal quality management.

A project management team was established with the project theme of "Reducing the rate of irrational emergency prescriptions". The director of the Pharmacy Department served as the team leader, and the multidisciplinary team consisted of the director of the Pharmacy Information Center, three clinical pharmacists, one evidence-based pharmacist, and one information engineer, totaling seven people. Both premerger locations were represented equally. The team leader clearly defined the goals to be improved as: ① Reducing irrational emergency prescriptions; ② Identifying and improving the main irrational issues; ③ Enhancing patient satisfaction with emergency visits; ④ Increasing physicians' recognition of the pre-approval system for prescriptions. Team members were reasonably assigned to ensure the smooth progress of the project.

Measure: The Measure phase offers a data-driven representation of the current situation, enabling teams to pinpoint problem areas and establish the groundwork for the subsequent stages of targeted development. The objective is to uncover the root causes of variances and establish a benchmark by which improvements can be evaluated. In this phase, teams gather accurate and comprehensive information.[22]

The project team conducted a month-by-month examination of the reviews of emergency prescriptions and pre-prescription reviews from May 2022 to May 2023. They meticulously recorded the names of departments, doctors, the quantity of irrational prescriptions, the types of irrational prescriptions, and the specific drug usage of irrational prescriptions. To comprehend the fundamental situation of irrational prescriptions across the entire hospital prior to the intervention, a total of 4299 irrational prescriptions in the emergency department were gathered before the intervention, with an irrational rate of 0.85%. Among them, the emergency internal medicine department had the largest number of irrational prescriptions, accounting for 63.50%. The primary cause of irrational prescriptions was the failure to adjust the drug dosage according to the patient's condition. Simultaneously, the project team visited five emergency departments and surveyed a total of 20 clinicians to collect information on patients at each time node during the emergency treatment process. The main problems identified were as follows: Firstly, patients were unfamiliar with non-professional drugs, and the Hospital Information System lacked drug instructions, making consultation impossible. Secondly, the 12-hour working hours from 8 am to 8 pm were overly saturated. Thirdly, the emergency pharmacy personnel were inaccurate in reviewing prescriptions.

Analysis: Before the intervention, there were a total of 508,647 emergency prescriptions, all of which were subject to pre-prescription review. Among them, 4299 prescriptions were determined by the system to be irrational, with an irrational rate of 0.85%. The proportion of irrational prescriptions showed a gradually increasing trend, as shown in Figure 2. The types of irrational drug use were classified into eight categories: inappropriate dosage, inappropriate

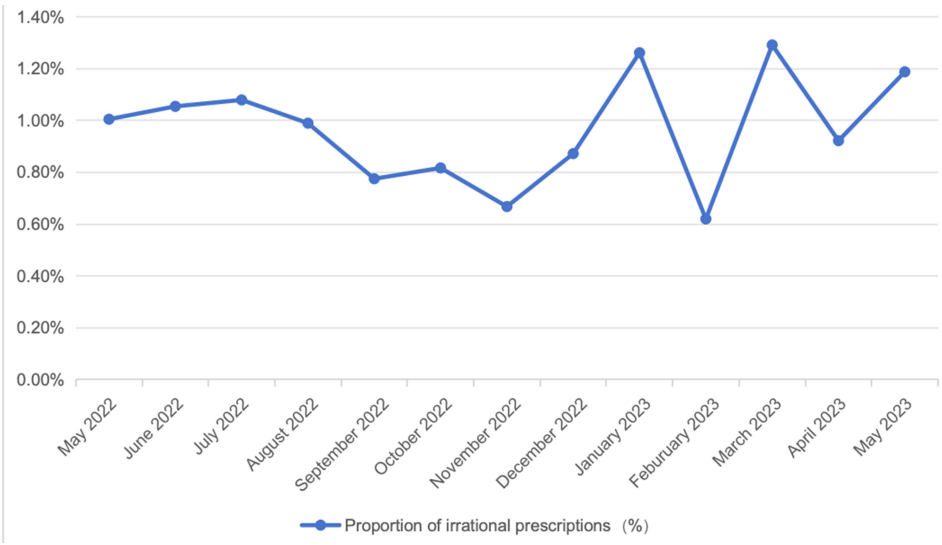

Figure 2 Proportion of irrational prescriptions in emergency department before intervention.

frequency, inappropriate route of administration, inappropriate combination of drugs, inappropriate course of treatment, duplicate medication, inappropriate selection of drugs, and contraindications. The irrational drug use situations and the departments that issued the irrational prescriptions were summarized to create a Pareto chart. The cumulative proportion in the 0–80% range was considered the main factor, the 80–90% range was the secondary factor, and the 90–100% range was the general factor. The main factors of irrational prescriptions were inappropriate dosage and inappropriate route of administration. The secondary factors were inappropriate frequency. The general factors were inappropriate course of treatment, inappropriate combination of drugs, inappropriate selection of drugs, contraindications, and duplicate medication. The types of irrational prescriptions are shown in Table 1 and Figure 3. The departments that issued the most irrational prescriptions were the emergency internal medicine and emergency urology departments, followed by the emergency pediatrics and emergency surgery departments. The departments that issued irrational prescriptions are shown in Table 2 and Figure 4. Based on the summarized data, a fishbone diagram was used to identify the root causes of irrational prescriptions from six elements: physicians, pharmacists, environment, system, management, and others, as shown in Figure 5.

Improve: Based on the above analysis of the irrational reasons, targeted optimization of key processes, formulation of operational rectification suggestions, and formulation of comprehensive improvement strategies. The Department of Pharmacy take the lead and work closely with clinical departments, information departments, medical affairs and other relevant functional departments to ensure the phased and effective implementation of the intervention measures. A sound closed-loop management system was established, including prescription pre-examination, real-time prescription intervention, prescription quality evaluation, result publicity and regular inter-departmental communication mechanism. The system is designed to ensure that the improvement plan meets and finally achieves the predetermined quality improvement goals, especially to achieve the fundamental purpose of reducing the irrational prescription rate in the emergency department within a specific time, and to improve the overall safety of patients' medication. Key improvements and detailed operational guidelines are as follows:

Monthly Review and Feedback Mechanism for Irrational Prescriptions

Every month, all irrational prescriptions identified by the prescription pre-review system were comprehensively reviewed by clinical pharmacists and evidence-based pharmacists. These prescriptions were classified by clinical departments, and the types of irrational prescriptions (such as inappropriate dosage, inappropriate frequency, inappropriate route of administration, inappropriate combination of drugs, etc.) were analyzed. For each department, detailed reports will be written highlighting the specific cases, the reasons for the unreasonability, and the potential risks that may be posed to the patient. Pharmacists and clinicians from each department will hold regular communication meetings. These meetings can take the form of one-on-one discussions of recurring issues by individual physicians or general practice meetings to address systemic issues. In addition, a hospital-wide report on Emergency Department irrational prescribing will be generated monthly, including the proportion of total irrational prescribing, the percentage of irrational prescribing in each department, the most common types of irrational prescribing, and typical irrational prescribing. The report will be

Table 1 Distribution of Contents and Factors of Irrational Prescription in Emergency Department Before Intervention

Types of Irrational Prescriptions	Number of Irrational Prescriptions (Sheets)	Ratio of Composition (%)	Cumulative Percentage (%)	Types of Factors
Inappropriate dosage	1643	38.22	38.22	A
Inappropriate route of administration	1186	27.59	65.81	A
Inappropriate frequency	899	20.91	86.72	B
Inappropriate course of treatment	331	7.70	94.42	C
Inappropriate combination of drugs	102	2.37	96.79	C
Inappropriate selection of drugs	84	1.95	98.74	C
Contraindications	33	0.77	99.51	C
Duplicate medication	21	0.49	100.00	C

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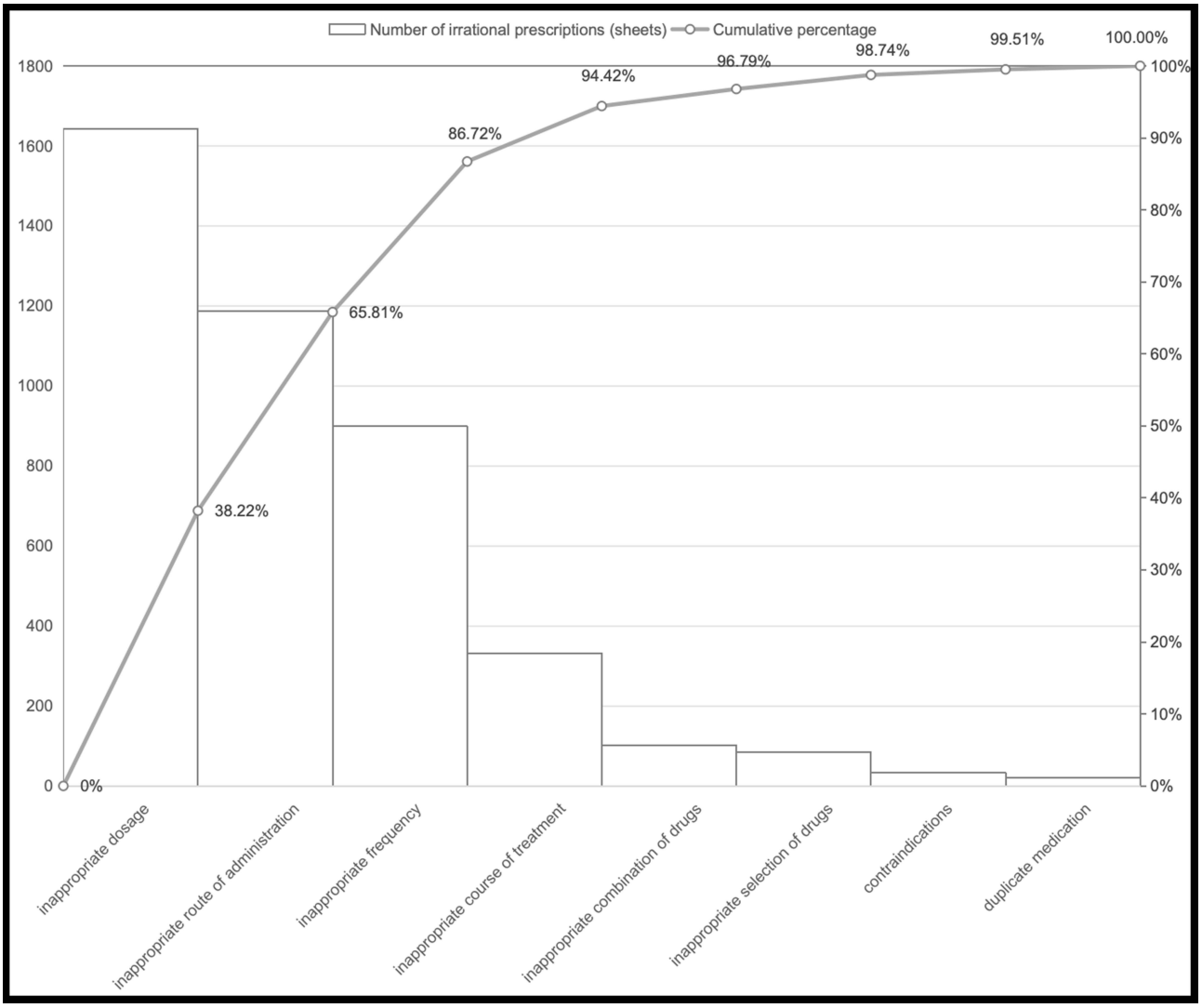

Figure 3 Pareto diagram of irrational prescription in emergency department before intervention.

displayed publicly, such as on the hospital's internal network platform, to enhance doctors' awareness of prescription norms.

Strengthening the Training and Assessment of Clinicians

In view of the irrational drug use problems (monthly review report), personalized training programs were developed to improve the level of rational drug use of doctors. Department-specific training sessions will be held at least once a quarter, and additional communication with clinical department heads will be made if specific emerging problems are identified. Training will cover the latest national and international clinical guidelines, the pharmacokinetics of a given drug, appropriate dose adjustment based on patient factors (eg, age, renal/liver function), and management of drug interactions. The training will be conducted through lectures, case studies, interactive discussions, etc. To ensure validity, the theoretical test will be evaluated after each training session, and the results will be linked to the annual performance evaluation of the physician. Noncompliant physicians scheduled mandatory retraining.

Enhancing the Competence of the Pharmacist Team

A structured capacity building program will be implemented to improve pharmacists' ability to review prescriptions. This includes regular in-house training led by senior title clinical pharmacists or external experts, focusing on new drug information, complex prescription analysis, and updates to clinical pharmacy practice. A clear emergency prescription

Table 2 Department Distribution and Factor Types of Irrational Prescriptions in Emergency Department Before Intervention

Emergency Department	Number of Irrational Prescriptions (Sheets)	Ratio of Composition (%)	Cumulative Percentage (%)	Types of Factors
Emergency medicine	2730	63.50	63.50	A
Urology emergency	442	10.28	73.78	A
Pediatric emergency Department	405	9.42	83.20	B
Emergency surgery	179	4.16	87.37	B
Emergency department of neurology	123	2.86	90.23	C
Emergency neurosurgery	86	2.00	92.23	C
Orthopedic emergency	70	1.63	93.86	C
Ophthalmic emergency	67	1.56	95.41	C
Emergency Department of Cardiology	66	1.54	96.95	C
Otolaryngology emergency department	58	1.35	98.30	C
Gynecological emergency	20	0.47	98.76	C
Emergency department of dentistry	19	0.44	99.21	C
Emergency department of plastic surgery and burns	19	0.44	99.65	C
Emergency obstetric care	7	0.16	99.81	C
Emergency vascular surgery	4	0.09	99.90	C
Emergency thoracic surgery	4	0.09	100.00	C

review system was established, and emergency pharmacy pharmacists were required to participate in the monthly emergency prescription review. The performance assessment system for pharmacists will be revised to incorporate prescription review work as a key indicator. Specifically, the accuracy and thoroughness of reviews, the number of irrational prescriptions identified and corrected, and contributions to reducing prescription errors will be weighted heavily in their performance evaluations, with corresponding incentives for outstanding performance.

Optimizing Hospital Information System (HIS) Support

The comprehensive medication and dosage information of all hospital drugs were integrated into the HIS database. When the doctor entered a drug, the system would automatically bring out the common usage and dosage of the drug. At the same time, a dialog box appeared on the doctor's working interface, which contained the drug instructions, such as the standard dose range, frequency, contraindications, potential drug interactions and common adverse drug reactions. Physicians could tailor prescriptions to the needs of individual patients but were required to document any reasons for off-label use. In addition, the package insert lookup feature at physician workstations will be upgraded to include searchable full-text versions of package inserts, updated regularly, and cross-referenced with clinical practice guidelines for quick access to evidence-based information.

Establishing a Dual Feedback Mechanism for Clinical Departments

To establish the active and passive feedback mechanism of clinical departments. Passive feedback will include regular analysis of frequent alert messages generated by the prescription review system. We will solicit feedback through monthly meetings with department representatives, at which physicians can report cases of unreasonable prescribing disputes (eg, a prescription that is labeled by the prescription review system as unreasonable but that clinicians deem to be justified). All the feedback collected was verified by clinical pharmacists and evidence-based pharmacists by cross-reviewing drug instructions, searching domestic and foreign authoritative databases (such as UpToDate, Micromedex), and reviewing relevant clinical guidelines and expert consensus. Based on this evidence-based review, the rules for the prescription pre-review system will be adjusted to reduce the incidence of false positive alerts, ensuring that the system remains rigorous and clinically relevant, as shown in Figure 6.

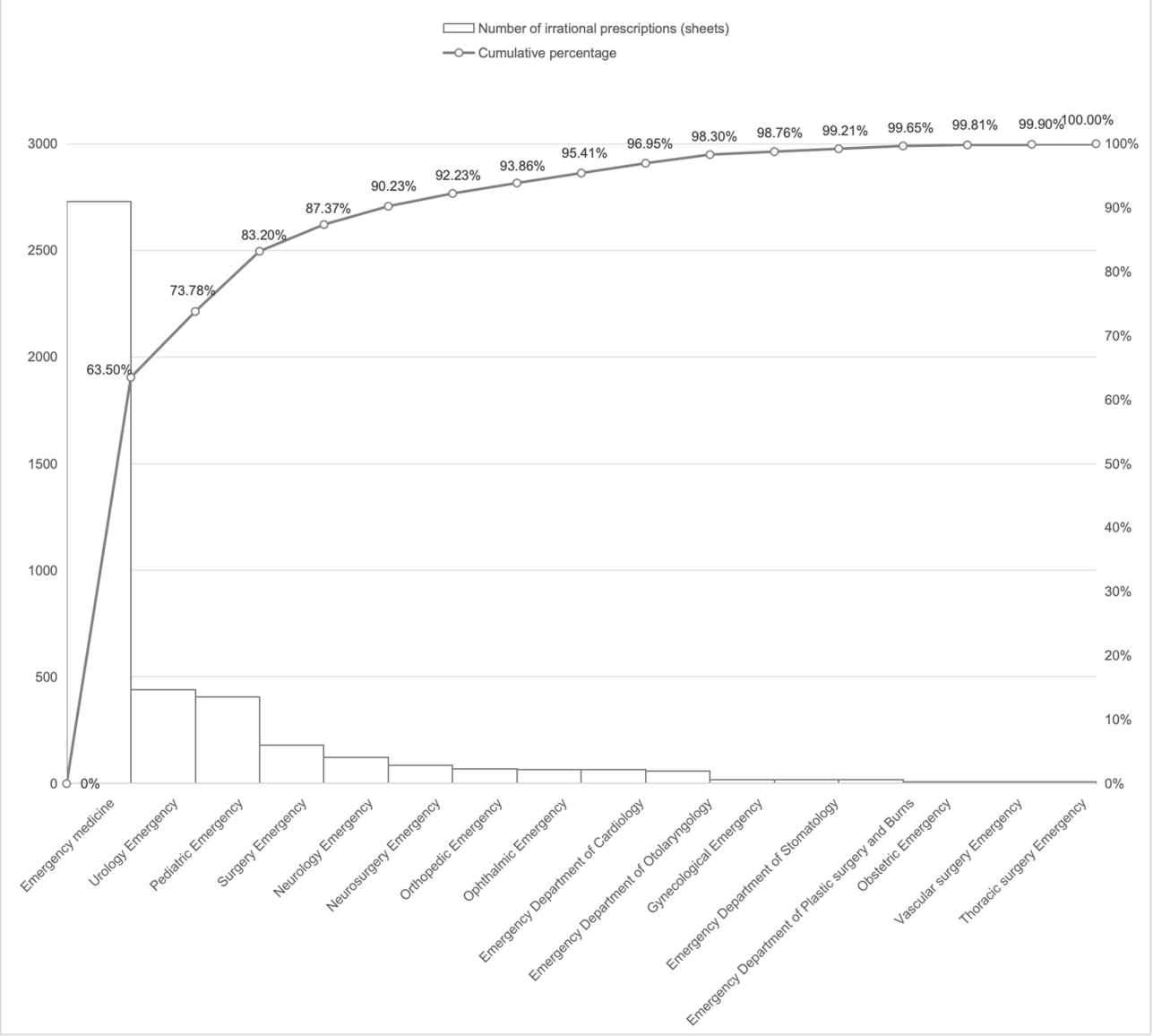

Figure 4 Pareto diagram analysis of irrational prescription distribution in emergency department before intervention.

Improving the Emergency Department Working Environment

Detailed analyses of patient flow patterns (eg, peak hours, seasonal fluctuations) were performed to dynamically adjust shift schedules. During periods of higher numbers (eg, weeknights, weekends, flu season), more physicians will be on duty to reduce the patient-physician ratio and ensure that each physician has enough time to assess cases and accurately prescribe. In addition, a "rescue rotation" system will be introduced to allow emergency department physicians to take short breaks of 15 to 20 minutes every 4 hours, with backup physicians assuming duties during these breaks to prevent disruptions in work. During peak hours, a clinical pharmacist is assigned to the emergency department to assist in confirming the rationality of prescriptions, checking the doses and potential interactions of common first aid drugs, and providing real-time technical support for doctors.

Control: Dynamic monitoring and continuous improvement should be carried out in view of the irration problems in the implementation process of the management plan. To achieve this, it is essential to develop standardized operating procedures to ensure that all improvements are effectively integrated into daily work, thereby consolidating their application and impact.

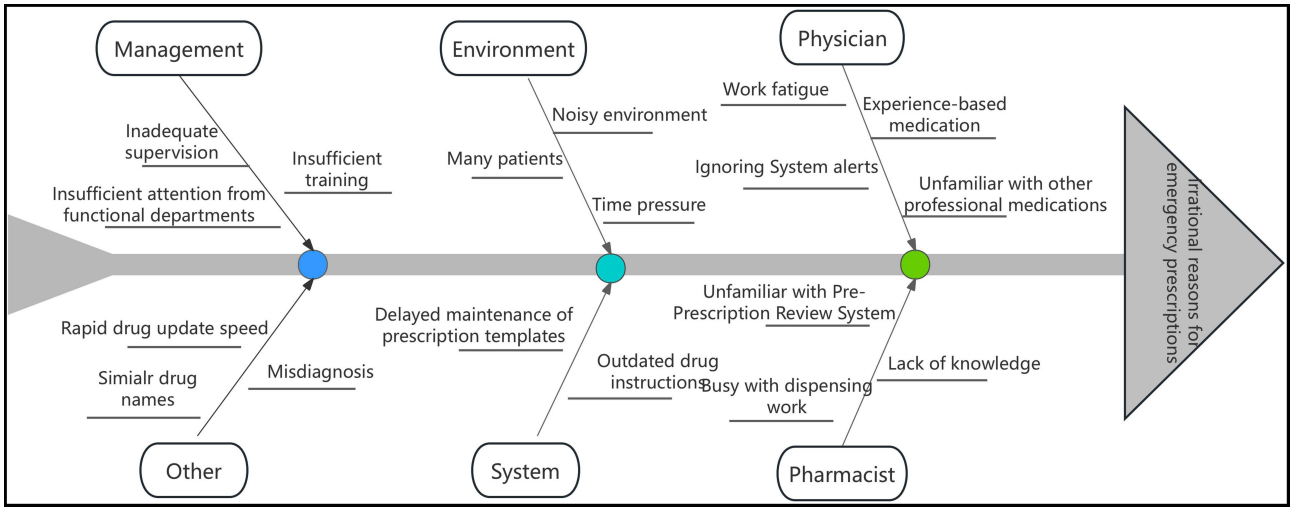

Figure 5 Fishbone diagram analysis of irrational emergency prescriptions.

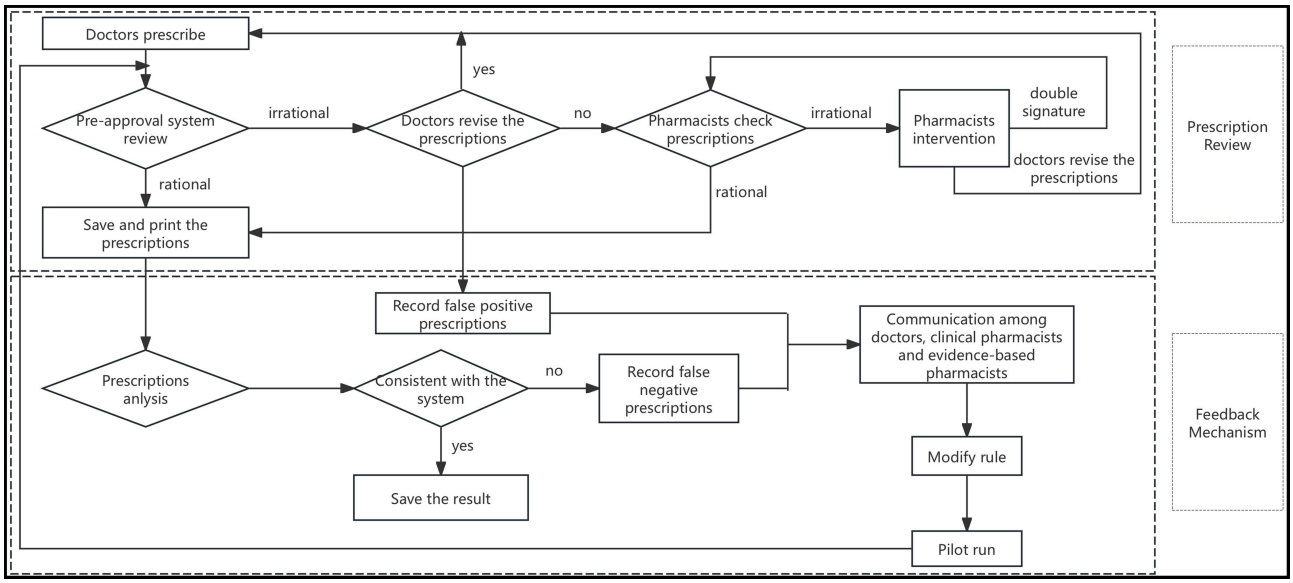

Figure 6 Workflow of diagram of pre-prescription and feedback mechanism.

Long-term monitoring mechanisms must be in place to continuously monitor. This includes regular collection of prescribing data and close monitoring of trends in prescribing plausibility. To improve transparency and accountability, comprehensive evaluations should be conducted on a monthly basis and the results published. In addition, regular quality control checks need to be implemented to maintain high standards throughout the process.

To enhance the competence of the personnel involved, training sessions and assessments should be organized regularly to ensure that all staff are familiar with the latest procedures and requirements. It is also critical to continuously proactively identify and resolve potential system problems, rather than waiting for system upgrades. Summarize the experience and lessons in time, consolidate the achievements, form a cycle of continuous improvement, and strengthen the overall effectiveness of the management plan.

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Evaluation Indicators

Inappropriate Prescription Rate in Emergency Department: According to the "Prescription Management Measures" and "Hospital Prescription Review Management Specifications (Trial)", the inappropriate prescription rate is calculated as (total number of prescriptions - number of reasonable prescriptions) / total number of prescriptions × 100%.

Trend of Inappropriate Prescription Rate in Emergency Department: The inappropriate prescription rate is statistically analyzed on a monthly basis and a trend chart is created.

Types of Inappropriate Prescriptions and Distribution by Department: A Pareto chart is made to display the types of inappropriate prescriptions and their distribution by department.

Patient Satisfaction: A self-developed satisfaction survey questionnaire is used to conduct a satisfaction survey of patients from dimensions such as medical experience, medical environment and medication guidance. The entries are scored using the Likert 5-level scoring system, with the grades being very satisfied, relatively satisfied, average, not very satisfied, and very not satisfaction is assigned 5, 4, 3, 2, and 1 points respectively. The total score is 100 points.

Rate of Physicians Returning to Modify Inappropriate Prescriptions: The proportion of physicians modifying inappropriate prescriptions and resubmitting them after the system identifies them as inappropriate.

Statistical Analysis

Data analysis is conducted using SPSS 25.0 statistical software. Quantitative data are expressed as ($\bar{x} \pm s$), and comparisons between the two groups are performed using *t*-tests; count data are expressed as rates, and comparisons between groups are performed using χ^2 tests. A difference is considered statistically significant if $P < 0.05$.

Results

Irrational Prescription Rate Before and After Intervention

Before the intervention, the number of prescriptions judged as irrational by the pre-review system was 4299, with an irrational rate of 0.85%. After the intervention, the number of irrational prescriptions was 2478, with an irrational rate of 0.43%. The irrational prescription rate in emergency department significantly decreased after the intervention, and the difference was statistically significant ($\chi^2 = 751.98$, $P < 0.001$).

Trend of Irrational Prescription Rate in Emergency Department

The proportion of irrational prescriptions in the emergency department showed a monthly decreasing trend before and after the intervention. In June 2024, after implementing LSS based on the pre-review system, the number of irrational prescriptions in the emergency department decreased by 0.42% compared to before the intervention ($P < 0.001$, 95% CI = [0.32, 0.81]), and the irrational prescription rate decreased at a rate of 0.07% ($P < 0.001$, 95% CI = [−0.06, 0.20]) month by month. The trend is shown in Figure 7.

Irrational Prescription Types and Department Distribution

By comparing the distribution of irrational prescriptions before and after the intervention, inappropriate dosage and inappropriate route of administration remained the main factors, as shown in Figure 8. However, except for combined medication, contraindications and repeated medication, other types of inappropriate prescriptions all decreased after the intervention compared to before, and there were statistically significant differences ($P < 0.05$), as shown in Table 3.

After the intervention, the emergency internal medicine department, pediatric emergency department and urology emergency department were the main departments where irrational prescriptions occurred, while the emergency orthopedics department, emergency surgery department, neurology emergency department and emergency reconstructive surgery department were the secondary departments, as shown in Figure 9.

Patient Satisfaction Before and After Intervention

A questionnaire survey was conducted before the intervention (January 3–10, 2023) and after the intervention (January 6–13, 2025). The questionnaires were distributed by the uniformly trained emergency nurses before the patients

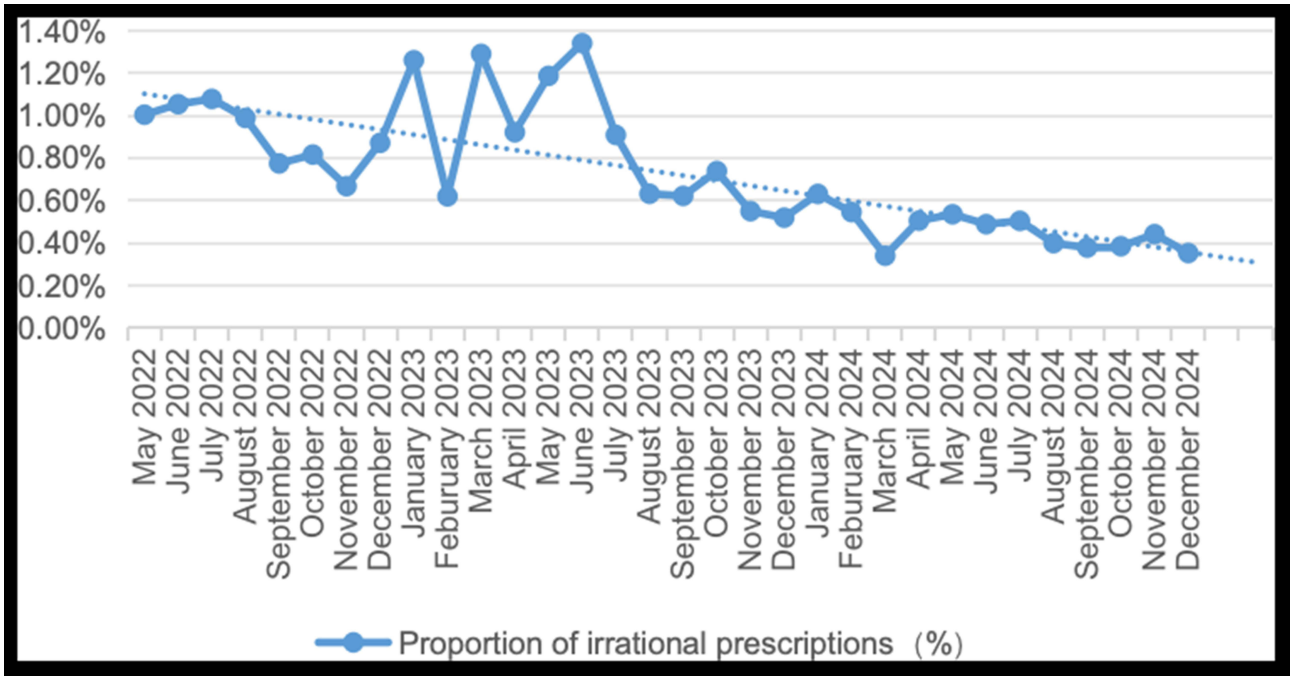

Figure 7 Trend of irrational rate of emergency prescriptions before and after intervention.

left the hospital, filled in anonymously, and recovered on the spot. A total of 480 questionnaires were distributed before the intervention, and 468 valid questionnaires were returned, with an effective recovery rate of 97.50%. After the intervention, a total of 480 questionnaires were distributed and 471 valid questionnaires were returned, with an effective recovery rate of 98.13%. The patient satisfaction score after the intervention was (92.5 ± 3.2) points, significantly higher than that before the intervention, which was (81.3 ± 4.5) points ($t = 5.45$, $P < 0.05$).

Rate of Returning and Revising Inappropriate Prescriptions by Physicians

After the prescription pre-audit system identified an inappropriate prescription, 1214 inappropriate prescriptions were returned and revised by physicians after the intervention (48.99%), and 1264 were continued to be prescribed (51.01%). Before the intervention, 1543 inappropriate prescriptions were returned and revised by physicians (35.89%), and 2756 were continued to be prescribed (64.11%). The proportion of physicians returning and revising inappropriate prescriptions after the intervention was significantly higher than that before the intervention, and the difference was statistically significant ($\chi^2 = 111.77$, $P < 0.001$).

Discussion

Theoretical Implications

The new national healthcare reform policy has set higher requirements for hospital pharmacy services. The informatization assistance strategy for pharmacy has become an indispensable and important tool in pharmacy services. By applying information technology, an efficient prescription review system can effectively enhance the efficiency of pharmacists' work and ensure the safety of clinical medication. However, the analysis of irrational prescriptions intercepted before they are prescribed found that the system inevitably has flaws or is not reasonable, resulting in frequent false positives or false negatives.[23] Frequent false positive problems may cause alert fatigue among prescription reviewers and physicians, thereby reducing the trust of physicians in the pre-review system and the efficiency of pharmacists, causing significant inconvenience to the prescription review process. Persistent false negative problems will directly affect the safety of patients' medication and the qualification rate of prescriptions.

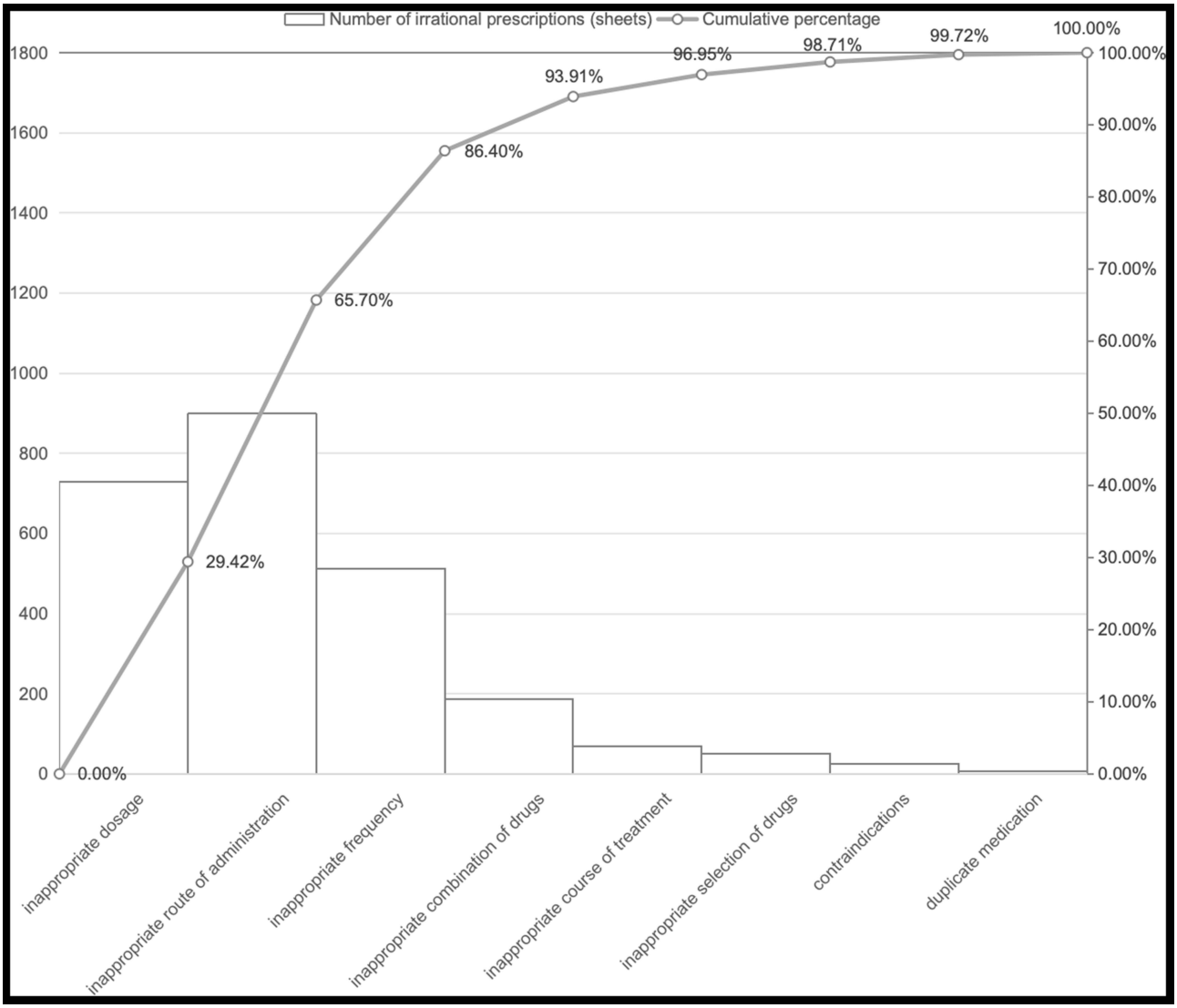

Figure 8 Pareto diagram of irrational prescription in emergency department after intervention.

This study innovatively integrated the prescription pre-review system with LSS, achieving a profound integration and innovative breakthrough of management methods and technical means. This combined application transcends the limitations of traditional single technologies or management models, and constructs a closed-loop management

Table 3 Comparison of the Distribution of Irrational Prescriptions in Emergency Department Before and After Intervention

Types of Irrational Prescriptions	Before Intervention ($\bar{x} \pm s$)	After Intervention ($\bar{x} \pm s$)	t	*P*
Inappropriate dosage	138.69±69.31	72.78±31.33	24.43	<0.001
Inappropriate route of administration	95.47±36.22	84.28±28.82	6.51	<0.001
Inappropriate frequency	74.99±22.27	46.74±13.65	24.28	<0.001
Inappropriate combination of drugs	8.97±3.97	17.09±4.44	−29.32	<0.001
Contraindications	2.60±1.44	3.96±1.65	−2.51	0.019
Inappropriate course of treatment	27.73±21.19	8.47±4.76	7.33	<0.001
Duplicate medication	1.71±1.60	3.00±1.29	−6.97	<0.001
Inappropriate selection of drugs	8.73±7.22	6.45±3.56	2.73	0.009

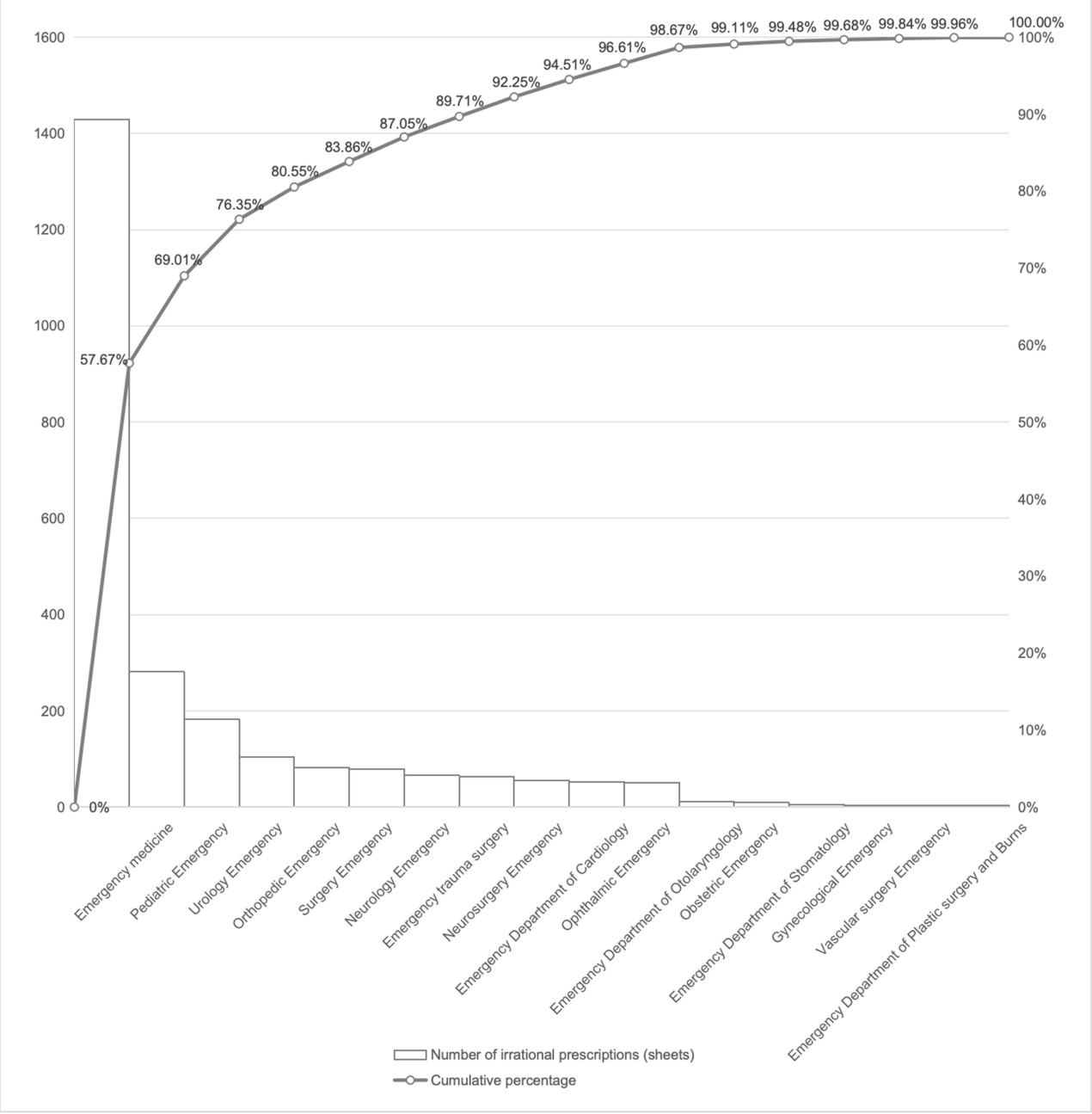

Figure 9 Pareto diagram analysis of irrational prescription distribution in emergency department after intervention.

theoretical framework of "problem identification-immediate intervention-continuous improvement". Rooted in the "patient-centered" concept of modern medicine, this framework deeply integrates personalized and rational drug use management rules with information technology. It not only offers a novel theoretical perspective for enhancing the quality of pharmaceutical care but also significantly enriches the theoretical connotation of clinical pharmaceutical care, providing robust theoretical support for hospitals to implement personalized and rational drug use management.

Moreover, this study comprehensively analyzed the false positive and false negative issues in the prescription pre-audit system, systematically expounded on the distinctive advantages of LSS in data mining and process optimization, and clearly disclosed the synergistic and complementary mechanism between information technology and the management model during the process of improving prescription quality. This outcome provides a valuable theoretical reference

for subsequent related research and effectively promotes the improvement and development of the theoretical system in the field of pharmaceutical care.

Practical Implications

In this study, through the collaborative intervention of prescription pre-review and LSS, data mining was employed to identify the primary types of irrational prescriptions. A comprehensive analysis was conducted on the causes of irrational drug use in the emergency department. Relevant regulations were improved, the work process was optimized, and the professional basic knowledge and skills of personnel were gradually enhanced. Notable outcomes were achieved in addressing the issue of irrational drug use in the emergency department. After the intervention, the irrational rate of emergency prescriptions decreased significantly and exhibited a favorable trend of continuous improvement. This effectively mitigated potential risks such as medication errors and drug interactions, and effectively safeguarded the medication safety and life-health of patients.

The main types of irrational prescriptions before and after the intervention were all inappropriate dosage and administration route, consistent with the results of a multicenter prospective study.[24] These inappropriate prescriptions mainly concentrated in the emergency internal medicine department, and the proportion of the department with the highest irrational prescriptions before and after the intervention was also the emergency internal medicine department. The primary reason is that patients in the emergency department present with complex conditions. A larger number of patients are under observation, and their conditions are relatively severe, with more complications. The conditions change rapidly, which involves a greater number of drug selections, drug combinations, and compatibility contraindications.[25] Specifically analyzing the reasons, the inappropriate administration route mainly includes two situations: one is accidental wrong opening, such as prescribing intravenous administration for oral preparations or oral preparations for intravenous administration, which is directly related to the busy work of emergency physicians; the other is incorrect intravenous route, such as intravenous drip of vitamin K1, the dosage of vitamin K1 injection only mentions intramuscular, deep subcutaneous injection or slow intravenous infusion in the instructions, but does not include intravenous drip, because the solvent dosage for intravenous drip is generally too large, and vitamin K1 has poor stability and is easily decomposed when exposed to light.[26] Moreover, the "Chinese Physician and Pharmacist Clinical Medication Use Guidelines" by the Rational Drug Use Expert Committee of the Ministry of Health mentioned that "intravenous administration can cause respiratory and circulatory accidents, and is only applicable to patients who cannot use other routes", indicating that the use of vitamin K1 should be cautious and should refer to the instructions. The inappropriate dosage is mainly encountered in pediatric emergencies, mainly caused by excessive single-dose or daily doses. For example, dosage conversion based on their weight is usually required when using antibacterial drugs in children. If the entire tablet (granule) is given directly, it may lead to an excessive dosage; some traditional Chinese medicine or anti-allergy drugs have dosages divided according to the age stage of children. If the clinical doctor is not familiar with the drug dosage, it may also lead to improper medication. However, the prescription pre-audit system cannot perform precise dosage conversion based on the patients' height, weight, and age. Given that the absorption, distribution, metabolism, and excretion processes of drugs in infants and young children differ significantly from those of adults, to reduce the risk of adverse drug reactions, personalized medication administration must be strictly based on factors such as the patient's age, height, and weight.[27] Therefore, for pediatrics, the issue of inappropriate dosage has become a difficulty. By analyzing the causes through LSS, the emergency pharmacy pharmacists were trained on the usage and dosage of common pediatric drugs.

For prescriptions with irrational system prompts, the window pharmacists can adjust the drug dispensing based on the actual situation of the patients. The prescription review pharmacists also regularly communicate with clinical doctors about special medication regimens and promptly update the review rules in the pre-audit system.[28] The urology department is also one of the main departments that issues irrational prescriptions. The problem lies in the inappropriate frequency, for example, "Phosphomycin Sodium for Injection 8g + 0.9% Sodium Chloride Injection 100mL qd ivgtt". Phosphomycin Sodium for Injection is a time-dependent antibiotic, and its efficacy depends on when the blood drug concentration is higher than the minimum inhibitory concentration (MIC) of the bacteria. It requires multiple administrations to kill bacteria and control the infection effectively. Therefore, the administration frequency should be increased, and a once-daily administration frequency is irrational.

The significant improvement in patient satisfaction is deeply correlated with the improvement in the rate of rational prescriptions. On one hand, the pre-review system for prescriptions reduces the need for repeated communication, refunds, re-prescribing, or secondary queuing due to irrational prescriptions, shortens the patient's visit time, and reduces the occurrence of doctor-patient conflicts.[29] On the other hand, rational drug use reduces the occurrence of adverse drug reactions, directly improving the treatment effect and safety. Moreover, optimizing processes by LSS has indirectly improved the efficiency of emergency services.[30] The improvement in patient satisfaction not only reflects the improvement in medical service quality but also strengthens the trust between doctors and patients, conforming to the modern medical concept of "patient-centeredness", indicating that this model not only improves the quality of prescriptions but also enhances the patient's medical experience and ensures medication safety.

Physicians' high recognition of the system is attributed to its clinical practicality and efficiency optimization. Traditional prescription reviews are mostly post-feedback, making it difficult for physicians to trace the root cause of the problem. However, the pre-review system provides immediate and visual rule prompts, helping physicians quickly correct prescriptions and reducing the pressure of clinical decision-making. Additionally, the results of Six Sigma analysis provide data-based medication references for physicians, assisting them in targeted improvements to prescription habits. The system's continuous optimization function enhances physicians' participation, shifting them from passive acceptance of reviews to active optimization of prescription quality. This "tool empowering clinical practice" model breaks the barrier between information technology and clinical practice, reducing the burden on physicians and increasing their efficiency, thereby enhancing their trust and reliance on the system.

Limitations

This study also has some limitations. For instance, the director of the pharmacy department leads the project management team, which has a certain team incentive effect, but the hospital management level is not involved. Since implementing the management model requires significant time and resources, the project team plans to pilot this solution in the initial stage. If the results are significant, the participation of the management level will be gradually expanded, and relevant data will be presented to senior leaders. Subsequently, senior leaders' support and active participation will become the key elements for the Project success. In addition, this study was conducted in a single center, where the hospital management model and patient structure may influence. Its universality needs to be verified through multi-center research. Moreover, the long-term dependence of physicians on the system and the adaptability of the rule library still require longer-term observation. Future research can further optimize the pre-review rule library by combining artificial intelligence technology, constructing an intelligent auxiliary prescription review system,[31] or mining potential needs through physician behavior analysis, promoting the iterative upgrade of system functions. Although there are some limitations, integrating LSS and the pre-review system has achieved the main goal of significantly reducing the rate of irrational prescriptions in emergency prescriptions.

Conclusions

In the global healthcare landscape, hospital pharmacies are critical nodes within the broader medical system, directly impacting patient care and healthcare delivery. Improvement of quality is a continuing requirement in healthcare. This research is the first to thoroughly integrate LSS with the pre-review system for prescriptions. It offers a standardized and replicable solution for emergency prescription management, contributes an innovative and efficient management approach to the domain of emergency medication management, notably reduces the incidence of irrational prescriptions, and enhances patient satisfaction. The project can inspire other hospitals to introduce quality and process improvement themselves. At the same time, management strategies and technical means should be continuously optimized to promote the continuous improvement of medical service quality.

Data Sharing Statement

All the data in the article are obtained by the authors themselves, and the pictures are also drawn by themselves. So no reference to any data set, all original.

Ethical Approval

No ethical approval is required for this article.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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