

A Retrospective Study on the Impact and Benefits of Commercial Clinical Decision Support Systems in Clinical Decision-Making and Pharmaceutical Care

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Purpose: Pharmacists ensure prescription accuracy to safeguard patient safety. Clinical decision support systems (CDSS), integrated with computerized physician order entry (CPOE), help detect medication errors and enhance care quality. Traditional homegrown CDSS (HG systems) require manual updates, while commercial CDSS offer real-time, curated drug data but come with licensing costs. To evaluate the impact and benefits of integrating a commercial CDSS with a CPOE system on clinical decision-making and pharmaceutical care in a Taiwanese medical center.

Patients and Methods: This retrospective study was conducted in a 1,354-bed teaching hospital in southern Taiwan in 2022. Alerts generated by a homegrown (HG) CDSS and a commercial CDSS, both integrated with CPOE, were compared. Fifty-six trained inpatient pharmacists reviewed prescription alerts. Effective alerts were defined as those initially missed by physicians but corrected after pharmacist intervention. Alerts were categorized by clinical issue type and severity. A model incorporating the probability of adverse drug events (ADEs), extended hospital stays, and daily costs was used to estimate cost savings. A benefit-cost ratio was calculated to assess the added value of the commercial CDSS.

Results: The commercial CDSS generated 357 effective alerts, and the HG system generated 251. Over 95% of pharmacist interventions were accepted by physicians. The commercial CDSS helped avoid inappropriate prescriptions, which resulted in estimated cost savings from USD 78,540 to USD 103,530 and reduced hospital stays by 470–620 days.

Conclusion: Using a commercial CDSS to assist pharmacists in prescription verification provides the most real-time information and efficiently identifies inappropriate prescriptions. This reduces medical costs and avoids prolonged hospitalization owing to ADEs.

Keywords: clinical decision support system, decision-making, pharmaceutical care, cost

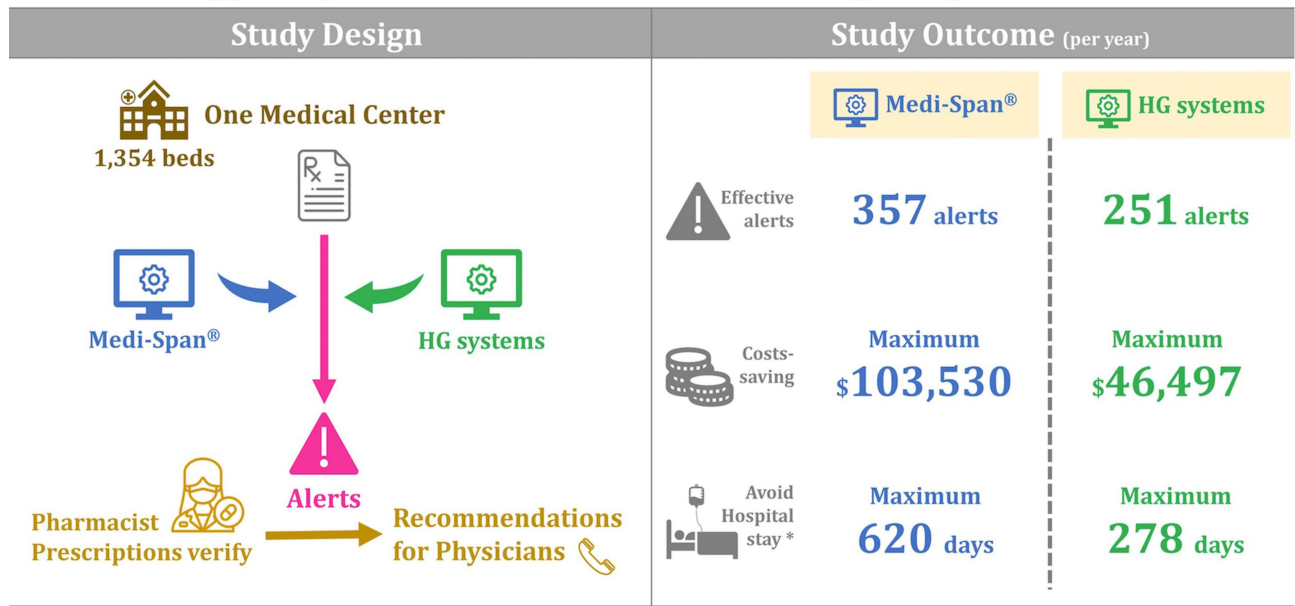
Introduction

Globally, approximately 400,000 hospitalized patients experience harm annually because of medication errors. This results in additional healthcare expenses of approximately USD 4 billion.¹ It has been indicated that over half of medication errors occur during the prescription phase.² With technological developments, computerized physician order entry (CPOE) systems have become widespread in healthcare institutions. This has significantly reduced the risk of prescription errors. Since the publication of the landmark report *To Err Is Human: Building a Safer Health System* by the Institute of Medicine in 1999, patient safety has become a central focus in healthcare reform. The report estimated that approximately 44,000 to 98,000 deaths occur annually in the United States owing to preventable medical errors, many of which are medication-related. Rather than blaming individuals, it emphasized the need for systemic improvements to reduce harm and enhance care quality.³ A key strategy involves leveraging health information technology—particularly clinical decision support systems (CDSSs)—to develop guidelines, care pathways, and protocols that enhance decision-



Graphical Abstract

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making, identify potential errors, and promote safer, evidence-based prescribing.⁴ CDSSs used for medication prescribing are digital tools that incorporate drug knowledge databases and integrate with CPOE systems. These systems provide prescription recommendations, assess clinical parameters, detect drug–drug interactions, and assist in calculating appropriate drug dosages. By leveraging individual patient data from electronic medical records (EMRs), CDSSs generate alerts for potential issues such as incorrect dosages, contraindications, duplicate therapies, and harmful interactions. These alerts enable pharmacists to intervene promptly and collaborate with physicians, thereby reducing the risk of adverse drug events (ADEs).^{4,5} Research shows that combining CPOE systems and CDSSs with alerts during prescription can reduce medication errors and ADEs by 12.5%. This will prevent approximately 17.4 million medication errors within one year.^{6,7}

Traditional CDSSs, often referred to as homegrown (HG) systems, are developed internally by pharmacists and information technology departments within healthcare organizations. These systems can generate flexible prescription alerts based on regional healthcare regulations and institution-specific needs. However, they typically require manual maintenance and literature review by pharmacists to update the drug knowledge database that supports alert generation during prescription verification, which is highly time-consuming. Integration with CPOE and EMR systems is often partial, sometimes requiring separate interfaces or manual workarounds.^{8,9} Additionally, these systems lack real-time updates and are prone to clinical judgment. Conversely, commercial CDSSs are developed by external vendors and are designed for seamless integration with CPOE and EMR systems, which enable real-time access to clinical data and immediate alert generation. These systems typically rely on expert-curated drug knowledge databases that are regularly and automatically updated, thereby reducing the workload on pharmacists. Implementation is generally faster because of standardized frameworks, and scalability is more feasible across institutions.⁴ Although commercial CDSSs offer immediate responsiveness and operational efficiency, they may impose a financial burden on healthcare institutions owing to annual licensing fees charged by vendors.⁴ Moreover, commercial CDSSs face challenges such as alert fatigue, unfriendly user interfaces, and difficult in customization according to regional regulations and medical institution

needs.¹⁰ The authors' institution is the first medical center in Taiwan to implement a commercial CDSS. Given the limited availability of concrete quantitative evidence evaluating the effectiveness and cost-efficiency of commercial CDSS adoption, this study was designed to address that gap.

Aim

This retrospective study aimed to analyze the impact and benefits of implementing a commercial CDSS integrated with a CPOE system on clinical decision-making and pharmaceutical care, in comparison with a commonly used HG system at a single medical center. The findings may serve as a reference for future optimization strategies and for other healthcare institutions considering the adoption of similar approach.

Materials and Methods

Setting

This study was conducted at the inpatient pharmacy of a medical center established in 1988 in southern Taiwan. The facility is a teaching hospital with approximately 1,354 beds. According to the standards set by the Taiwan Ministry of Health and Welfare, approximately one pharmacist is required for every 40 general beds and one for every 20 intensive care unit beds. Inpatient pharmacists are responsible for drug dispensing, inventory management, prescription verification, medication reconciliation for new inpatients, therapeutic drug monitoring, providing medication-related consultation to healthcare professionals, and addressing any concerns related to prescriptions. Medi-Span[®], a commercial CDSS developed by Wolters Kluwer Inc., is extensively used in healthcare settings to provide medication-related alerts, such as dosing recommendations, drug interactions, contraindications, and therapeutic duplications. Its proprietary generic product identifier (GPI) enables precise therapeutic classification, whereas the clinical application programming interface (API) integrates patient-specific data with trusted, evidence-based databases, including Lexicomp[®] and UpToDate[®] to deliver real-time alerts. By factoring in patient-specific details—such as dosing, allergies, and ongoing therapies—this commercial CDSS supports healthcare providers across workflows from e-prescribing to therapy management, which help to reduce preventable adverse drug events (ADEs).¹¹ The system was implemented at the study site in 2021 as part of a hospital-wide initiative to improve prescription verification.

Study Design and Data Collection

This retrospective study was conducted between January 2022 and December 2022. During this period, prescription alerts detected by the HG system or commercial CDSS within the inpatient CPOE system were collected and reviewed. A total of 56 inpatient pharmacists participated in the evaluation. Inpatient pharmacists typically undergo a two-year post-graduate year training program, supplemented by comprehensive medication management courses under the intern pharmacist preceptor training program. These training programs focus on patient-centered pharmacist care, including identifying drug-related problems, assessing patient pharmacotherapy, developing therapeutic plans, and monitoring treatment outcomes.¹² Therefore, they help mitigate variability in alert evaluations caused by human factors.

Workflow for Commercial CDSS and HG System

Figure 1 is accompanied by a clear narrative in the main text describing the differences in alert timing and system integration between the HG system and the commercial CDSS. After a prescription issued for an inpatient, one pharmacist verifies the prescription and dispense the medication, while another pharmacist checks the accuracy of the dispensing. The HG system and commercial CDSS function independently but in parallel. However, the difference in process is that the HG system performs real-time checks when a physician issues a prescription and triggers an alert (Figure 1a). In contrast, the commercial CDSS updates the pharmacist's review interface every 15 min with potential medication issues. It classifies the alerts into four severity levels of alerts with pharmacists required to assess and document level 1 alerts (most severe, Table S1) in the system (Figure 1b). If a pharmacist deems a prescription inappropriate, they can contact the physician by phone or through the CPOE system, recording the intervention in the CPOE system.

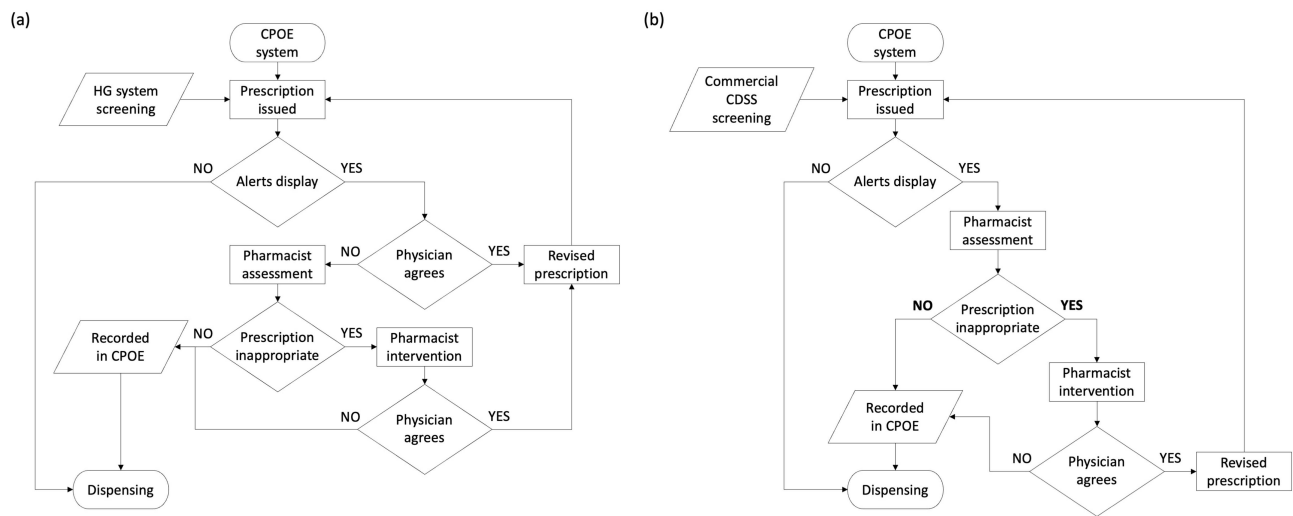


Figure 1 The workflow of HG system and commercial CDSS system. **(a)** The workflow of HG system. **(b)** The workflow of commercial CDSS system. **Abbreviations:** CPOE, computerized physician order entry; HG, homegrown; CDSS, Clinical Decision Support Systems.

Effective Alert

Drawing on a previous study,⁷ we classified the alerts of the commercial CDSS and HG systems with CPOE into seven categories: dosage, duration, route, indication, contraindication, drug-drug interaction, and duplication. Table 1 provides a brief description of the alert types and highlights the differences between the two systems. Although a situation where the physician changes the prescription immediately upon seeing the alert is considered an effective alert, this study defined alert as an “effective alert” only when it was initially overlooked by the physician, later assessed by the pharmacist, who provides recommendations to the prescribing physician, and the physician accepts the recommendation and changes the prescription.

Table 1 Alert Types in Commercial CDSS and HG Systems

Alert Type	Commercial CDSS	HG System
Dosage		
	1. Dose type (initial, single, maintenance) 2. Usual daily dose and form (usual range, maximum dose) 3. Frequency (usual range, maximum dose)	1. Frequency and dosage 2. Cumulative dose in a specific period 3. Maximum single dose (including loading dose) 4. Maximum daily dose 5. Maximum daily frequency 6. Maximum dose for pediatrics
Duration		
	Duration (usual range, maximum range)	Duration of total quantity per drug
Routes		
	Route or dosage form	Route or dosage form
Indications		
	Disease diagnosis	Disease diagnosis

(Continued)

Table 1 (Continued).

Alert Type	Commercial CDSS	HG System
Contraindications		
	1. Disease diagnosis (ICD code) 2. Pregnancy 3. Age 4. Gender	1. Drug allergy history 2. Pregnancy 3. Age
Drug-drug Interactions		
	Interaction	Interaction
Duplications		
	Duplicated therapy	1. Duplicated drug 2. Duplicated drugs with similar pharmacological mechanisms

Abbreviations: HG, homegrown; CDSS, Clinical Decision Support Systems; ICD, International Classification of Diseases.

Cost Analysis

Because effective alerts generated by the commercial CDSS or HG system can detect medication errors, they play a crucial role in preventing ADEs and reducing healthcare expenses. In this study, a cost-saving model was applied to estimate the potential savings from pharmacist-reviewed alerts produced by these systems. This analysis aimed to explore the added value of integrating a commercial CDSS into pharmaceutical services alongside the existing HG systems. The benefit-cost ratio (BCR) analysis was conducted from the perspective of hospital decision-makers.^{13,14} Previous studies reported that the probability of ADEs (P) ranges from 0.00 (no harm) to 0.60 (high harm).¹⁵ Subsequently, the number of avoided ADEs (N) was estimated based on the effective alerts. Drawing on previous studies,^{16,17} we conservatively assumed that each ADEs resulted in an additional hospital stay of 2.2 to 2.9 d (D). The cost per day of hospitalization (C) included diagnosis fees, nursing fees, drug costs, and pharmaceutical care costs, estimated at USD 167 according to National Health Insurance (NHI) data¹³ (currency: USD/NTD = 30). Therefore, the final cost savings were calculated as $P \times N \times D \times C$. After obtaining the savings, we also calculated the benefit-cost ratio in two manners: (1) the cost savings per effective alert of commercial CDSS divided by the annual purchase cost of commercial CDSS (USD 40,000/year) and (2) the cost savings per effective alert of the HG system divided by the average pharmacist salary (approximately USD 26,667/year).¹³

Statistical Analysis

Descriptive statistics were used to estimate the number of effective alerts identified by pharmacists using the commercial CDSS and HG systems, as well as the probability of preventing ADEs. The statistical analyses were performed using SPSS 17.0.

Results

Between January 2022 and December 2022, a total of 39,860 and 116,060 potential prescription errors were detected by the commercial CDSS and HG systems, respectively. Among them, 1.44% and 5.21% of prescriptions were immediately changed by the physicians based on the alert content at the time of prescribing. Table 2 presents the distribution and types of effective alerts identified by pharmacists in both systems. Of the alerts initially overlooked by physicians, 357 (0.91%) and 251 (0.23%) were later reviewed by pharmacists, who provided recommendations to the prescribing physicians that led to further changes in the prescriptions. These instances are defined as “effective alerts” in this study. Among the effective alert, 296 (83%) involved dosage issues, followed by drug–drug interactions and contraindications. Physicians accepted and rejected the recommendations of pharmacists in 351 (98.3%) and six (1.7%) cases, respectively. Dosage issues were also dominant (117 alerts, 47%) in the effective alerts from the HG system, followed by duplicate therapy orders and contraindications. There were 240 (95.6%) and 11 (4.4%) cases in which physicians accepted and rejected pharmacist consultations, respectively.

Table 2 Effective Alerts for Commercial CDSS and HG Systems

Alert Type	Commercial CDSS, N (%)	HG System, N (%)
Total	357	251
Dosage	296 (82.9)	117 (46.6)
Duration	0 (0.0)	19 (7.6)
Routes	0 (0.0)	19 (8.6)
Indications	0 (0.0)	7 (2.8)
Contraindications	19 (5.3)	20 (8.0)
Drug-drug interactions	42 (11.8)	1 (0.4)
Duplications	0 (0.0)	68 (27.0)

Abbreviations: HG, homegrown; CDSS, Clinical Decision Support Systems.

Table 3 Cost Savings of Effective Alerts in Commercial CDSS and HG Systems

Alert Type	Probability Score	Numbers		Probability Score × Numbers	
		Commercial CDSS	HG system	Commercial CDSS	HG system
Dosage	0.6	296	117	177.6	70.2
Durations	0.1	0	19	0	1.9
Routes	0.1	0	19	0	1.9
Indications	0.4	0	7	0	2.8
Contraindications	0.6	19	20	11.4	12
Drug-Drug Interactions	0.6	42	1	25.2	0.6
Duplications	0.1	0	68	0	6.8
Total		357	251	214.2	96.2
Total cost avoidance * (USD)				78,540 ~ 103,530	35,273 ~ 46,497

Notes: * Total cost avoidance = sum of probability score × numbers × (2.2–2.9) × 167 (currency of USD/NTD = 30).

Table 3 presents the estimated cost savings and avoided hospital days based on effective alerts, and includes the calculated benefit–cost ratios for each system. The estimated cost savings in 2022 owing to pharmacists finding inappropriate prescriptions with the assistance of commercial CDSS and HG system alerts were USD 78,540–103,530 and USD 35,273–46,497, respectively. The prevention of ADEs in patients could result in a reduction in hospital stay of 470–620 d and 211–278 d, respectively. Based on the expected cost savings, the benefit–cost ratios for the commercial CDSS and HG systems were 1.96–2.59 and 1.32–1.74, respectively.

Discussion

This is the first study in Taiwan to investigate the cost-effectiveness of preventing medication errors through the implementation of a commercial CDSS from the perspective of pharmacists. Over the course of one year, 357 inappropriate prescriptions were intercepted with the support of the commercial CDSS, resulting in estimated cost savings of USD 78,540–103,530 associated with ADE prevention. Furthermore, over 95% of pharmacist recommendations based on effective alerts from both the commercial CDSS and HG systems were accepted by physicians, leading to corresponding prescription modifications.

Types of Effective Alerts

Dosage

Errors related to dosage or frequency were prevalent in both the commercial CDSS and HG systems in this study. This is consistent with previous research, indicating that medication-dosing errors are frequently observed during hospitalization, particularly in patients with renal insufficiency.¹⁸ Antibiotics, famotidine, and hypoglycemic drugs accounted for 40% (N = 119), 13% (N = 37), and 10% (N = 28), respectively. Carbapenems and cephalosporins were the most commonly used antibiotics. Antibiotic dosages vary depending on different clinical infection conditions, and several antibiotics require dosage adjustments based on renal function owing to pharmacokinetic factors. Therefore, when patients are closely monitored for renal function during hospitalization, inappropriate medication dosages and frequencies in prescriptions can be easily identified by the CDSS.¹⁹ One key advantage of commercial CDSS is their ability to provide real-time updated data tailored to patient's overall clinical profile. These systems incorporate variables such as indications, special conditions (eg, dialysis modality), age, weight, body surface area, and renal function. By integrating this information, the commercial CDSS can generate dosing recommendations across range checks across complex clinical scenarios, ensuring a more personalized and safe approach to medication management.

Drug–Drug Interactions

Drug interactions can affect treatment outcomes, causing fluctuations in drug concentrations or altering the pharmacological effects. Implementing drug interaction alerts in the CDSS ensures the safe and effective use of pharmacotherapy. These alerts can help pharmacists to assess and provide immediate medication therapy recommendations. They can also prevent harm to patients owing to drug interactions, including insufficient efficacy or increased side effects. Due to limited labor resources, only one or two pharmacists at the medical center were responsible for maintaining the HG system's drug interaction information. As several drugs are cytochrome P450 inducers or inhibitors, the information volume of drug-drug interactions is also quite extensive. Therefore, remembering all this information is difficult for pharmacists. However, establishing drug interaction alerts is tedious and time consuming, resulting in only a few absolute combination contraindications being included in the HG system.

During the coronavirus disease 2019 (COVID-19) pandemic, pharmacists specifically added drug interaction alerts that were associated with the treatment of COVID-19 (such as nirmatrelvir/ritonavir) to the HG system. Owing to the reduced number of inpatients at that time for reasons other than COVID-19 infection, all drug interaction alerts provided by the HG system during the study period were related to nirmatrelvir and ritonavir. Nonetheless, alerts in commercial CDSS are updated monthly and cover a wide range of inhibitors and inducers of cytochrome P450.²⁰ During the research period, the commercial CDSS was more effective than the HG system in intervening with drug interactions in prescriptions because it provided more alerts related to other drugs, such as the interaction between carbapenem and valproic acid. Commercial CDSS significantly saves the time spent by pharmacists on maintaining drug interaction data. This enables them to assess drug interactions in prescriptions efficiently and focus on participating in clinical care.

Indications and Contraindications

Although the commercial CDSS and HG systems have similar numbers of contraindication alerts, the definitions of the alerts differ between these two systems (Table 1). In the HG system, contraindication alerts are triggered when a physician prescribes a drug to which the patient has a documented drug-related allergies or adverse reactions in the EMR. However, aside from pregnant women, the HG system does not provide information on drug contraindications based on physiological or pathological conditions. Additionally, accurately linking each International Classification of Diseases (ICD) code to the indications or contraindications of the drug is challenging for pharmacists. Any omissions or incorrect associations with disease classification codes provide incorrect information and burden the system. Therefore, data on alerts related to drug indications and contraindications in the HG systems are limited. Furthermore, owing to Taiwan's unique nationwide mandatory single-payer NHI system, medication use is limited to indications covered by NHI regulations. Consequently, in this study, the HG system verified indications only for certain drugs based on Taiwan's NHI reimbursement criteria. In contrast, commercial CDSS platforms are equipped with built-in drug indication

databases that can automatically cross-reference patient diagnosis ICD codes within the medical record system, thereby enabling a more effective evaluation of medication appropriateness based on the patient's clinical background.

Barriers and Opportunities for Improvement

Lack of Interoperability

Despite the continued advancements in commercial CDSS, challenges remain achieving integration across healthcare institutions.⁸ For instance, in the medical center's electronic medical records (EMRs), ICD codes are recorded in three distinct locations: admission records, discharge records, and progress notes documented by physicians during hospitalization. Although commercial CDSS are supported by comprehensive databases, their alerting capabilities may be limited by inconsistently structured EMRs and a lack of interoperability between systems.²¹ A feasible solution is to collaborate with IT teams to establish patient records through secure cloud services and blockchain technology, thereby providing more accurate patient data and facilitating better integration between the CDSS and healthcare institution systems.²² These measures could improve the quality and consistency of information and enhance the effectiveness of the CDSS in various healthcare settings.

Alert Fatigue

When irrelevant or inappropriate alerts occur, alert fatigue ensues, which causes users to ignore the alerts, regardless of their importance.¹¹ For example, in our study, several drug interactions and contraindications related to high blood potassium levels appeared in the commercial CDSS records. This was primarily because the commercial CDSS checks ICD codes based on the admission records of patients, but it cannot verify laboratory test values or conditions. During the hospitalization of the patient, even after the correction of their serum potassium level, commercial CDSS identified contraindications related to hyperkalemia, such as when medications that could cause high blood potassium were prescribed, leading to alert fatigue.²³

A study found that optimizing alerts for cases with hyperkalemia significantly reduced the alert burden by 92.8%.²⁴ Methods for addressing alert fatigue include regularly analyzing effective and ineffective alerts, prioritizing those that are more important and impactful, and setting alert triggers based on clinical needs and severity. The CDSS should incorporate the laboratory test values or other characteristics of patients to generate more personalized alerts and recommendations, thereby reducing alert fatigue.²⁵

Impact on Cost-Effectiveness

Analyses of the cost savings for both the commercial CDSS and HG systems show their benefits, consistent with the results of previous studies related to CDSSs.^{14,26,27} The commercial CDSS implementation enables more preventable ADEs to be discovered, and can reduce the hospitalization days and expenses of patients. A US medical center conducted a financial analysis comparing monthly cost savings from pharmacist interventions before and after implementing a commercial CDSS, using long-term financial data. The results showed that monthly cost savings increased from USD 127,467 to USD 249,959 following implementation, thereby resulting in an annual increase of USD 1,469,907 and a year-over-year growth rate of 96%. Although the study did not reveal the setup and maintenance costs of the commercial CDSS, it emphasized the direct cost savings observed in real-world settings, which reflect the system's significant contribution to improving pharmacist efficiency and medication decision-making.¹⁴ Another study evaluating the implementation of a commercial CDSS used a multi-method data collection strategy, including on-site observations to assess changes in inpatient surgical order processing efficiency, as well as analyses of medical records and system data to examine changes in order authentication, hospital length of stay, and medical expenses. The findings showed that across various types of surgical procedures—including heart and other organ transplants, general surgery, and oncology—the commercial CDSS significantly reduced total costs per patient, with savings ranging from USD 393 to USD 671 in contrast to scenarios without the system.²⁸ In contrast, our study employed a benefit-cost ratio model that focuses on hospital days and associated healthcare costs saved through “effective alerts” that help prevent ADEs. This approach provides a more detailed foundation for clinical decision-making and risk management.

Although the commercial CDSS products, evaluation models, and objectives differed across studies, all demonstrated that CDSS can significantly enhance the value of pharmacist interventions and lead to substantial reductions in healthcare costs. In our cost-effectiveness calculation, we adopted the formula:

$$(P) \times (N) \times (D) \times (C),$$

where P is the probability of an ADE, N denotes the number of avoided ADEs, D represents the additional hospital stay per ADE (in days), C is the cost per hospital day.

Among these variables, only N was derived from our study data. The values for P and D were drawn from previously published literature, whereas C was based on current healthcare costs in Taiwan. However, we acknowledge that healthcare regulations, insurance policies, and clinical practices vary significantly across countries and even among institutions. Therefore, the values referenced in our model may not be universally generalizable. Given the conservative nature of our estimates, the actual cost-effectiveness of the commercial CDSS interventions may have been underestimated. This study serves as a reference for assessing the impact of implementing a commercial CDSS and provides a conservative estimate of its role in supporting pharmacists in reducing medication-related costs within healthcare institutions. By adopting a conservative estimation approach, the findings prioritize reliability while acknowledging that the actual impact of the system may be elevated than reported.

Limitation

The assumptions in our cost-effectiveness analysis have certain limitations: (1) In our setting, alerts generated by the commercial CDSS were available to clinicians in real time during the prescribing process but were displayed to pharmacists on every 15 min. Given this time lag, if a physician modified a prescription based on an alert before pharmacist review, the associated prevention of ADEs was not captured in the outcome measurements of this study. Therefore, the clinical and economic effectiveness reported may be underestimated. Additionally, this study did not include a formal power analysis or statistical measures of—such as confidence intervals or standard deviations—in the cost-benefit calculations, which may limit the precision, interpretability, and generalizability of the findings. As a retrospective analysis, our model primarily relied on deterministic inputs derived from existing literature and institutional data, particularly regarding the probabilities of ADEs and hospitalization costs. These inputs inherently lacked variability estimates. While this approach provides a conservative estimate of potential cost savings, it may underestimate the true impact. Future research should incorporate prospective data collection and probabilistic modeling to better capture parameter uncertainty and enhance the robustness of cost-effectiveness assessments. (2) Minor differences in how alert categories are defined and implemented across the two systems limit the comparability of cost saving estimates. (3) The impact of CDSS interventions is influenced by various factors, including the specific environment and technology. This study did not account for other relevant costs, such as personnel resources or the time required for system maintenance and alert optimization, which may affect the overall results.²⁹ However, as this is still a relatively new research area, further exploration and standardized quantitative indicators are required to analyze the financial impact of CDSSs in the future.

Pharmacist's Role in CDSS

The pharmacist's role in enhancing the relevance of a CDSS is crucial for ensuring the system provides accurate, timely, and context-specific recommendations that align with best practices in patient care. CDSS is only as effective as the data it uses, pharmacists can help enhance the system by ensuring it considers the following factors: (1) patient history: pharmacists can ensure that the system integrates relevant patient data, such as allergies, comorbidities, and previous adverse drug reactions. (2) clinical guidelines: pharmacists can help update the system with the latest evidence-based guidelines, clinical protocols, and therapeutic recommendations that are tailored to specific patient populations (eg, pediatric, geriatric, or patients with chronic diseases).^{22,30}

Pharmacists also can collaborate with physicians, nurses, and other healthcare professionals to ensure the CDSS is integrated seamlessly into the clinical workflow. This collaboration can help to identify usability issues within the system and work with IT teams to make the interface more user-friendly. Finally, as experts in drug therapy and patient care, pharmacists are well-

positioned to provide continuous feedback on the CDSS. By analyzing outcomes, identifying gaps in the system, and assessing areas for improvement, they can ensure that the system evolves to meet the changing needs of clinical practice.^{18,25}

Conclusion

This study demonstrated that implementing a commercial CDSS in an inpatient setting can significantly reduce medication-related alerts, enhance prescribing safety, and improve cost-effectiveness by minimizing unnecessary interventions. The findings support the study's objectives and are consistent with existing literature. However, because the study was conducted at a single center, the generalizability of the results may be limited. Future research should adopt multi-center, longitudinal designs to evaluate broader impacts, compare different types of CDSSs, assess user adoption, and examine clinical outcomes. Expanding the analyses to outpatient and emergency care settings could further clarify the effectiveness of CDSSs across diverse healthcare environments.

Data Sharing Statement

The data associated with this study are available upon request to the first author. (Lu-Hsuan Wu, email: lan_w007@hotmail.com).

Ethics Approval

All study protocols were approved by the Institutional Review Board of the National Cheng Kung University Hospital [No. A-ER-112-463]. All methods were performed following the relevant guidelines and regulations of the Institutional Review Board and the Declaration of Helsinki.

Informed Consent

The research data were provided by the Taiwan NHI, which have been deleted, and the individuals cannot be identified. Our study was approved by the Institutional Review Board, and informed consent was not obtained from any of the subjects. The authors confirm that the PI for this paper had direct clinical responsibility for patients.

Acknowledgments

We are grateful for the technical services provided by the Health Outcome Research Center at the National Cheng Kung University Hospital and Belle Chang from Wolters Kluwer Inc.

Funding

This study received grants from National Cheng Kung University Hospital (grant numbers: NCKUH-11407002, NCKUH-114070008, and NCKUH-11409004).

Disclosure

The authors report no conflicts of interest in this work.

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