



Original Article

Impact of a Renal Function–based Clinical Decision Support System in Reducing Inappropriate Prescribing: A Pre-post Intervention Study at a Vietnamese Tertiary Hospital

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Abstract: Background: Inappropriate prescribing in patients with renal impairment, including the use of contraindicated drugs and unadjusted doses, is a significant contributor to preventable adverse drug events. Clinical Decision Support Systems (CDSS) have been shown to reduce medication errors by providing real-time alerts during prescribing. This study aimed to evaluate the effectiveness of a renal-related prescribing alert system integrated into the hospital's CDSS at a Vietnamese Tertiary Hospital. Methods: A pre-post interventional study was conducted over two three-month periods: before (June–August 2024) and after (December 2024–February 2025) the implementation of renal-related prescribing alerts in the CDSS. The intervention included (1) building a database of contraindicated and dose-adjusted drugs based on renal function, (2) integrating the database into the Hospital Information System (HIS), and (3) training prescribers on the alert function. Data were extracted from the electronic prescribing system and analyzed using Chi-square tests to compare pre- and post-intervention outcomes. Results: After CDSS implementation, the proportion of patients with at least one contraindicated drug decreased from 6.0% to 1.5%, and prescriptions containing at least one contraindicated drug decreased from 4.5% to 2.1% ($p < 0.05$). Likewise, the proportion of patients receiving at least one unadjusted dose decreased from 6.1% to 0.4%, and prescriptions requiring dose adjustment decreased from 4.0% to 0.8% ($p < 0.05$). Overall, inappropriate prescriptions related to renal function were reduced by

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69.5% (from 1,307 to 399 cases). The most frequent inappropriate prescribed drugs after intervention were furosemide + spironolactone (28.6%), trimetazidine (22.3%), and amlodipine + valsartan + hydrochlorothiazide (15.8%). Conclusions: Integration of renal-related prescribing alerts into the CDSS significantly reduced inappropriate prescribing in patients with renal impairment. These findings highlight the potential of CDSS to enhance medication safety and prescribing quality, though continuous optimization and user engagement are needed to sustain long-term effectiveness.

Keywords: Clinical Decision Support System, CDSS, renal function, contraindicated drugs, dose adjustment, prescribing appropriateness, medication safety.

1. Introduction

Inappropriate prescribing among patients with renal impairment either through the use of contraindicated medications or failure to adjust dosages according to renal function remains a major clinical concern. Previous studies have reported that 20–67% of prescriptions for patients with renal insufficiency are inappropriate in terms of drug selection or dosing adjustment, and up to one-third of hospitalized patients with impaired renal function receive at least one potentially harmful medication. Such prescribing errors have been associated with a two- to threefold increase in adverse drug events (ADEs), prolonged hospital stays, and higher treatment costs. Collectively, these findings highlight the urgent need for systematic interventions to improve prescribing appropriateness and enhance medication safety in patients with renal impairment [1]. Therefore, the early identification, appropriate management, and optimization of drug selection and dosing in patients with impaired renal function play a crucial role in minimizing medication-related harm and improving clinical outcomes.

In recent years, Clinical Decision Support Systems (CDSS) have emerged as an effective technological intervention to address medication safety challenges. These systems provide timely alerts and evidence-based recommendations to ensure that prescribing decisions, including drug choice and dosage, are appropriate for patients with renal dysfunction [2-7]. Numerous studies have demonstrated that CDSS implementation can significantly enhance patient safety, improve the quality of care, and reduce healthcare costs [8-10].

In Vietnam, the National Digital Health Transformation Program 2020 and Circular No. 54/2017/TT-BYT issued by the Ministry of Health established technical requirements for CDSS as part of hospital information system (HIS) standards. In alignment with these national initiatives, many healthcare institutions have begun integrating CDSS into their electronic prescribing and clinical workflow systems to support physicians in making safer and more accurate medication decisions.

At Vietnamese Tertiary Hospital (Ha Dong General Hospital), where hundreds of thousands of patients are examined and treated annually, minimizing medication-related errors has become an urgent priority. The hospital has implemented an integrated Hospital Information System (HIS) and is developing a CDSS module embedded within the Computerized Physician Order Entry (CPOE) platform. This system generates alerts related to renal function covering both contraindicated medications and dose adjustments to support clinicians in optimizing drug therapy for each patient.

Given this context, the present study was conducted to evaluate the effectiveness of renal-related prescribing alerts within the hospital's Clinical Decision Support System in reducing inappropriate prescribing among patients with renal impairment.

2. Methods

2.1. Study Subjects

The study included all electronic prescriptions and medication orders for patients

treated at Ha Dong General Hospital during two periods: from June to August 2024 (pre-intervention phase) and from December 2024 to February 2025 (post-intervention phase).

In addition, audit trail data and system-generated reports on renal-related prescribing alerts were retrieved from the hospital's Hospital Information System (HIS) between December 1, 2024, and February 28, 2025, to assess alert activity and physician responses.

2.2. Study Design

This was a prospective interventional study employing a pre-post design to evaluate the effectiveness of the implemented CDSS alerts.

2.3. Study Procedure

The study consisted of three main phases:

i) Pre-intervention phase (June 1 – August 31, 2024): Baseline assessment of prescribing practices related to renal function before CDSS alert implementation.

ii) Intervention phase (September 1 – November 30, 2024)

Development and implementation of renal-related prescribing alerts within the hospital's CDSS. The intervention included:

(1) Establishing a list of medications requiring renal dose adjustment or contraindicated (contraindication) in renal impairment.

Integrating this database into the Hospital Information System (HIS).

(2) Conducting staff training sessions and providing clinical guidance on the use of CDSS alerts related to renal function.

(3) Deploying the alert system hospital-wide and collecting feedback from prescribers actively.

At the time of the study, the renal-related prescribing alert system integrated into the hospital's Clinical Decision Support System (CDSS) was being piloted. The alert database comprised 37 active ingredients classified as contraindicated drugs and 27 active ingredients requiring renal dose adjustment, including 41

single agents and 14 fixed-dose combinations (see Appendix 1). The database was developed through a comprehensive review of Prescribing Information (PI) of brand-name medications available in Vietnam. In cases where originator information was not available, the summaries of product characteristics (SPCs) from the European Medicines Compendium (EMC) were consulted, together with data from standard pharmacotherapy references such as *Renal Pharmacotherapy, 2nd edition (2021)*, the Vietnamese Ministry of Health's Guidelines for Diagnosis and Treatment of Chronic Kidney Disease and Related Renal Conditions, and relevant drug monographs from UpToDate (accessed September 2022) [11, 12].

iii) Post-intervention phase (December 1, 2024 – February 28, 2025): Assessment of inappropriate prescribing related to renal function after implementing CDSS system.

2.4. Outcome Indicators

The effectiveness of the CDSS intervention in reducing inappropriate prescribing related to renal function was evaluated using the following indicators, measured before and after implementation.

i) Proportion of prescriptions containing ≥ 1 contraindicated drug based on renal function;

ii) Proportion of patients receiving ≥ 1 contraindicated drug based on renal function;

iii) Proportion of prescriptions containing ≥ 1 drug with an unadjusted dose according to renal function;

iv) Proportion of patients receiving ≥ 1 drug with an unadjusted dose according to renal function.

In addition, descriptive analyses were performed to characterize the number and types of drugs that remained inappropriately prescribed according to renal function after CDSS implementation.

2.5. Outcome Assessment

To assess these indicators, data were extracted from the Hospital Information System

(HIS; FPT eHospital) in Excel format and cross-checked against the following sources: the list of active ingredients included in the alert database, inpatient and outpatient patient ID, and hospital medication summary reports.

Each prescription was evaluated for appropriateness based on renal function using the predefined alert database integrated into the CDSS, which classified drugs into two categories: (1) contraindicated for renal impairment and (2) requiring dose adjustment. A prescription was considered inappropriate if it contained at least one contraindicated drug or one drug prescribed at an unadjusted dose relative to the patient's estimated glomerular filtration rate (eGFR) or creatinine clearance (CrCl).

2.6. Data Processing and Analysis

All prescribing and alert data extracted from the Hospital Information System (HIS; FPT eHospital) were cleaned, standardized, and merged using Microsoft Excel before analysis.

Descriptive statistics were used to summarize patient characteristics and prescribing patterns. The proportions of inappropriate prescriptions and affected patients were compared between the pre- and post-intervention periods using the Chi-square test. Statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA),

with a significance level of $p < 0.05$ considered statistically significant.

3. Results

3.1. Frequency of Contraindicated Prescribing According to Renal Function Before and after the Intervention

Table 1 presents the characteristics of prescriptions containing contraindicated drugs with respect to renal function before and after CDSS implementation. During the three-month pre-intervention period, data were reviewed from 5142 patients, 11464 prescriptions, and 30755 prescribed drug orders. Among these, 622 instances (2.0%) of drugs contraindicated for the patients' renal function were identified, corresponding to 521 prescriptions and 306 patients who received at least one contraindicated medication. Following CDSS implementation, the total number of reviews was expanded to 5975 patients, 11759 prescriptions, and 14996 prescribed drug orders. The number of contraindicated prescriptions markedly decreased to 257 instances (0.9%), identified in 252 prescriptions involving 89 patients. These findings demonstrate a clear reduction in the frequency of prescribing contraindicated medications for patients with renal impairment after the introduction of renal-related prescribing alerts in the CDSS.

Table 1. Frequency of contraindicated prescriptions according to renal function before and after CDSS implementation

Indicator	Pre-intervention		Post-intervention	
	Number of reviews	Number of inappropriate instances	Number of reviews	Number of inappropriate instances
Contraindicated orders, n (%)	30755	622 (2.0%)	14996	257 (0.9%)
Patients with ≥ 1 contraindicated drug, n (%)	5142	306 (6.0%)	5975	89 (1.5%)
Prescriptions with ≥ 1 contraindicated drug, n (%)	11464	521 (4.5%)	11579	252 (2.1%)

After the intervention, the proportion of patients receiving at least one contraindicated

drug decreased significantly from 6.0% to 1.5%, and the proportion of prescriptions containing at

least one contraindicated drug decreased from 4.5% to 2.1% ($p < 0.05$). This highlights the positive impact of CDSS implementation on improving appropriate prescription in patients with renal impairment.

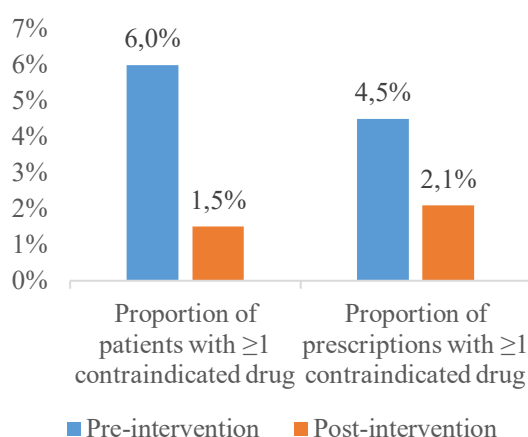


Figure 1. Frequency of unadjusted prescribing according to renal function before and after the intervention.

Table 2 summarizes the scope of data collection and findings related to dose adjustment based on renal function. In the pre-

intervention phase, a total of 34126 prescribed drug orders from 6365 patients and 14089 prescriptions were reviewed. After the implementation of CDSS alerts, the study sample increased to 34126 drug orders from 9796 patients and 16645 prescriptions.

The number of prescriptions containing drugs with unadjusted doses according to renal function decreased markedly from 685 to 132 instances, indicating a positive impact of the CDSS intervention on clinical prescribing practice. A similar reduction was observed in related indicators: the number of prescriptions containing at least one unadjusted drug decreased from 562 to 131, and the number of patients receiving at least one unadjusted drug declined from 387 to 42.

Following CDSS implementation, the proportion of patients receiving at least one drug without appropriate dose adjustment decreased significantly from 6.1% to 0.4%, while the proportion of prescriptions containing at least one unadjusted drug decreased from 4.0% to 0.8% ($p < 0.05$). These results confirm the effectiveness of the CDSS alert system in improving renal dose appropriateness in clinical practice.

Table 2. Frequency of prescriptions with unadjusted drug doses according to renal function before and after CDSS implementation

Indicator	Pre-intervention		Post-intervention	
	Number of review	Number of inappropriate instances	Number of review	Number of inappropriate instances
Unadjusted drug orders, n (%)	34126	685 (2.0%)	34126	132 (0.4%)
Patients with ≥ 1 unadjusted drug, n (%)	6365	387 (6.1%)	9796	42 (0.4%)
Prescriptions with ≥ 1 unadjusted drug, n (%)	14089	562 (4.0%)	16645	131 (0.8%)

When analyzed by clinical department, the Department of Internal Medicine accounted for the largest number of inappropriate prescriptions related to renal function in both study periods, although substantial reductions were observed following CDSS implementation. Specifically, the number of contraindicated prescriptions

decreased from 517 to 249, and prescriptions requiring dose adjustment declined from 662 to 128.

Within the Department of Internal Medicine, the Cardiology Department and the Nephrology–Urology Department exhibited the highest rates of inappropriate prescribing after the

intervention, representing 39.1% and 16.3% of all post-intervention cases, respectively.

In contrast, the Department of Surgery showed fewer instances of inappropriate prescribing overall; however, two cases of increased contraindicated prescriptions were

recorded after the intervention and warrant further review. Other departments demonstrated positive outcomes, with more than a 50% reduction in both contraindicated and unadjusted prescriptions following the CDSS rollout.

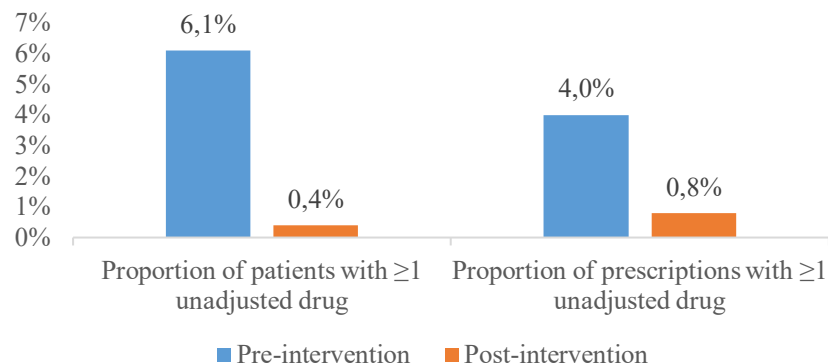


Figure 2. Distribution of inappropriate prescriptions by clinical department.

Table 3. Distribution of inappropriate prescriptions related to renal function by clinical department before and after CDSS implementation

Clinical division	Pre-intervention		Post-intervention	
	Contraindicated prescriptions (N = 622)	Dose adjustment required (N = 685)	Contraindicated prescriptions (N = 267)	Dose adjustment required (N = 132)
<i>Department of Internal Medicine</i>	517	662	249	128
Cardiology	221	158	88	68
Nephrology–Urology	89	22	48	17
Intensive Care & Toxicology	76	5	38	6
Endocrinology	71	453	9	6
<i>Department of Surgery</i>	8	2	11	1
Orthopedics	1	–	3	1
Neurosurgery	–	–	1	–
Urological Surgery	–	2	–	–
<i>Other departments</i>	59	21	7	3

Overall, the implementation of renal-related CDSS alerts effectively reduced inappropriate prescribing across most clinical departments, particularly within internal medicine units. These results suggest that the system was successfully integrated into daily clinical workflows and contributed to safer prescribing practices for patients with renal impairment.

3.2. Characteristics of Drugs Remaining Inappropriately Prescribed after CDSS Implementation

Table 4 summarizes the characteristics of drugs that continued to be prescribed inappropriately after the implementation of CDSS alerts at Ha Dong General Hospital.

Overall, the total number of inappropriate prescriptions related to renal function decreased by 69.5%, from 1307 cases before the intervention to 399 cases after the CDSS rollout.

Among the 12 reported drugs, three agents accounted for the highest proportion of inappropriate prescribing (each exceeding 10% of all cases): furosemide + spironolactone (28.6%), trimetazidine (22.3%), and amlodipine + valsartan + hydrochlorothiazide (HCT) (15.8%).

A total of 132 prescriptions involved drugs that were not appropriately dose-adjusted for renal function. The majority of these were associated with trimetazidine (81 cases, 61.4%), followed by saxagliptin (28 cases, 21.2%) and zoledronic acid (13 cases, 9.8%),

Meanwhile, prescriptions for contraindicated drugs occurred approximately twice as frequently as those for unadjusted

doses, encompassing 10 active ingredients. Among them, furosemide + spironolactone represented the largest proportion (42.7%, $n = 114$), followed by amlodipine + valsartan + HCT (23.6%, $n = 63$).

Most of the reported drugs demonstrated at least one type of inappropriate prescribing issue—either contraindicated use or lack of renal dose adjustment—with the exception of trimetazidine and zoledronic acid, which appeared in both categories.

These results highlight that, although the CDSS significantly reduced inappropriate prescribing, certain commonly used cardiovascular and metabolic agents remained prone to misuse in patients with renal impairment. Continuous updates to the alert database and targeted prescriber education are therefore essential to further optimize the system's clinical impact.

Table 4. List of drugs inappropriately prescribed after CDSS implementation at Ha Dong General Hospital

Drug	Frequency of inappropriate prescriptions (N = 399)	Contraindicated for renal function (N = 267)		Unadjusted dose for renal function (N = 132)	
	<i>n</i> (%)	<i>n</i>	%	<i>n</i>	%
Furosemide + spironolactone	114 (28.6)	114	42.7	—	—
Trimetazidine	89 (22.3)	8	3.0	81	61.4
Amlodipine + valsartan + HCT	63 (15.8)	63	23.6	—	—
Saxagliptin	28 (7.0)	—	—	28	21.2
Dabigatran	20 (5.0)	20	7.5	—	—
Zoledronic acid	15 (3.8)	2	0.7	13	9.8
Dapagliflozin	14 (3.5)	14	5.2	—	—
Empagliflozin	12 (3.0)	12	4.5	—	—
Capecitabine	11 (2.8)	11	4.1	—	—
Ceftriaxone	8 (2.0)	—	—	8	6.1
Desmopressin	5 (1.3)	5	1.9	—	—
Oxaliplatin	5 (1.3)	5	1.9	—	—

4. Discussions

The findings of this study indicate that, prior to the implementation of the Clinical Decision Support System (CDSS), prescribing for patients with renal impairment at Ha Dong General Hospital remained suboptimal. The proportion of patients who received at least one

contraindicated drug reached 6.0%, and 4.5% of prescriptions contained at least one contraindicated medication. These figures highlight a persistent problem of inappropriate prescribing related to renal function in clinical practice.

The most frequent issues were associated with diuretic combinations such as furosemide + spironolactone, which were commonly

prescribed despite contraindications due to their potential to cause dehydration, hypotension, and hyperkalemia, thereby worsening renal dysfunction. Likewise, medications such as dabigatran (an anticoagulant) and amlodipine + valsartan + hydrochlorothiazide (an antihypertensive combination) were also frequently prescribed inappropriately, posing increased risks of bleeding or progressive renal deterioration.

Before CDSS implementation, the rate of unadjusted dosing reached 6.1% and 4.0% among patients and prescriptions, respectively. The most common agents involved were metformin (44.3% of 510 prescriptions) and saxagliptin (31.6% of 598 prescriptions), which can lead to lactic acidosis or toxic accumulation in patients with a creatinine clearance below 30 mL/min. These problems were mainly concentrated in the Department of Internal Medicine (517 contraindicated and 662 unadjusted prescriptions), where most patients had multiple comorbidities, and in outpatient care (775 inappropriate prescriptions) where clinicians often face time pressure and heavy workloads.

Following CDSS implementation, a marked improvement was observed. The proportion of patients receiving contraindicated drugs decreased significantly from 6.0% to 1.5% ($p < 0.05$), and those receiving unadjusted doses fell from 6.1% to 0.4% ($p < 0.05$). The proportion of prescriptions containing contraindicated drugs also decreased from 4.5% to 2.1%, and those requiring dose adjustment decreased from 4.0% to 0.8%. Overall, the total number of inappropriate prescriptions declined by 69.5%, from 1307 to 399, with the largest reduction observed in the outpatient setting (88.5%). These findings demonstrate that the CDSS effectively enhanced physicians' ability to identify contraindications and adjust drug doses appropriately based on renal function.

The positive impact of CDSS interventions has also been confirmed by previous studies in Vietnam. For example, Le Thi Bach Nhu et al., [4] conducted a retrospective analysis of 401 medical records and reported that the proportion

of prescriptions requiring renal dose adjustment decreased from 38.2% to 19.7%. Similarly, Nguyen Viet Khanh [13] found that inappropriate renal dosing decreased from 52.7% to 10.6%. Variations between studies may be explained by differences in study design, sample size, patient characteristics, medication use patterns, and hospital information system structures.

The positive impact of CDSS interventions has also been confirmed by previous studies in Vietnam. For example, two recent studies, by Le Thi Bach Nhu et al. [4] and Nguyen Viet Khanh [13], both reported that the use of a CDSS led to a substantial reduction in the rate of inappropriate drug dose adjustment among hospitalized patients with impaired renal function. These Vietnamese studies highlighted the effectiveness of a comprehensive model where the CDSS alerts were integrated with clinical pharmacist intervention. Variations observed between studies may be explained by differences in study design, sample size, patient characteristics, medication use patterns, and hospital information system structures.

The present study leveraged a large dataset from the hospital's HIS, encompassing both inpatient and outpatient settings, to assess the system's effectiveness through a pre-post interventional design. However, several limitations should be acknowledged. Firstly, the study was conducted over a relatively short period (June 2024 – February 2025), coinciding with the transition to a new hospital formulary, which might have influenced prescribing patterns. Secondly, the three-month post-intervention period may not fully capture the long-term impact of the CDSS on prescribing behavior. Additionally, the audit trail data only recorded overridden alerts, rather than all alerts generated by the system, which limits the ability to analyze physicians' viewpoint to CDSS recommendations. Finally, the study did not assess patient-level outcomes such as reductions in adverse drug reactions or hospitalizations, which would provide stronger evidence of clinical benefit. Future research should therefore explore the longitudinal effects of CDSS

interventions and their direct impact on patient safety outcome.

5. Conclusions

A high rate of renal function-related inappropriate prescribing was observed before CDSS implementation. The introduction of renal-related prescribing alerts significantly reduced contraindicated and unadjusted dose medication use, demonstrating the CDSS's effectiveness in improving medication safety. Sustained benefits will depend on continued system refinement, workflow integration, and prescriber education.

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