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AI-Enhanced Medication Management for Acute Kidney Injury in Critical Care Settings

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Abstract

Background: Acute kidney injury (AKI) is a frequent complication in critically ill patients and is often exacerbated by inappropriate medication dosing and exposure to nephrotoxic drugs. Rapid renal function changes and high medication burden in the intensive care unit (ICU) make renal-safe prescribing challenging. Artificial intelligence (AI)-assisted clinical decision support systems may aid medication optimisation during AKI.

Objective: To evaluate the association between AI-assisted medication review and renal dose appropriateness in critically ill patients with AKI, and to assess AKI progression and renal recovery during ICU admission.

Methods: A single-centre observational study was conducted in an adult ICU. Adult patients diagnosed with AKI using the Kidney Disease: Improving Global Outcomes (KDIGO) criteria and receiving at least one medication were included. Renal function was monitored using serum creatinine and urine output. Medications were assessed for renal dose appropriateness. An AI-assisted decision support tool provided dosing and nephrotoxicity recommendations without autonomous prescribing during routine clinical care settings.

Results: Patients had a mean age of 63 ± 12 years and received multiple medications during AKI. Renal dose appropriateness improved from 66% to 85% following AI-assisted review. Renal function improved in 44% of patients, while 23% experienced worsening AKI.

Conclusions: AI-assisted medication review was associated with improved renal-safe prescribing in critically ill patients with AKI, supporting its role as a clinician-centred adjunct in intensive care.

Keywords: Acute kidney injury, Artificial intelligence, Medication safety, Renal dose adjustment, Intensive care unit

Introduction

Acute kidney injury (AKI) is a prevalent and severe clinical complication among critically ill patients, especially in the intensive care unit [1]. Defined by a high rate of renal failure, AKI is linked to a high rate of morbidity, long stay in hospitals and high healthcare consumption [2]. According to the epidemiological data, a substantial percentage of patients admitted to hospitals acquire AKI in cases of critical illness, the severity of which varies between mild, temporary creatinine levels and severe renal failure with the necessity of renal replacement therapy [3]. In addition to acute renal failure, AKI is also being considered as a cause of poor renal outcome in the long-term (such as failure to recover normal kidney function and chronic renal failure). As a result, one of the key priorities in modern renal medicine is prevention of preventable renal injuries during AKI episodes [4]. Exposure to medication is a significant aspect of AKI onset, progression and resolution that is modifiable. The patients that are critically ill are often subjected to complicated courses of medication which involve

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nephrotoxic medications, medications that need renal dose adjustment and medications with a slim therapeutic index [5]. The shift in pharmacokinetics in the presence of AKI, together with the quick changes in renal function, also makes the safe use of medication more complex. Poor dose adjustment or slow identification of nephrotoxic potential can worsen the renal damage, increase the duration of recovery, or cause irreversible kidney failure [6].

Past clinical studies have shown that there is a high prevalence of medication-related issues among patients with AKI. In trials assessing prescribing habits in the intensive care unit, it has been reported that there are often inconsistencies with guideline-based renal dosing, especially at the early phases of kidney damage [7]. Nephrotoxic drugs (some antimicrobials, nonsteroidal anti-inflammatory drugs, and contrast agents) are still frequent causes of such preventable renal impairment [8]. Although dosing recommendations are available according to the estimated glomerular filtration rate or serum creatinine, there is no adherence in the real world. The conventional clinical decision support frameworks utilised in the hospital environment are mainly based on the fixed laboratory limits or vague warnings [9]. These methods usually do not consider the dynamic renal patterns, trends of urine output, or the burden of medication [10]. The other barrier is alert fatigue that results in desensitisation and decreased clinical responsiveness. Nephrology consultation enhances the optimisation of the medication, but not all patients are provided with it in real-time, especially in resource-sufficient or acuity-based settings [11].

Digital health has seen recent innovations that embed the idea of artificial intelligence-based tools that can combine various clinical variables at the same time [12]. In renal medicine, there has been an increased focus on how such tools can be used to aid in the early identification of AKI and the use of the most effective treatment plans [13]. Nonetheless, the current body of information has provided much emphasis on the model of prediction or advanced algorithmic scheming, restricting their acceptance by the clinic as it raises the issue of interpretability, generalizability, and regulatory controls [14]. There is limited evidence comparing the use of simplified systems based on AI assistance in medication management amidst established AKI.

Although there are already renal dosing protocols in place, the incidence of medication-associated kidney injury is still high in critically ill patients with AKI [15]. Traditional procedures of prescribing are usually based on infrequent laboratory evaluation and hand-dose modification, which offers the chance to commit mistakes when renal function is subject to swift transformation [16]. The existing electronic decision support tools can produce too many alerts without the appropriate clinical context, decreasing their usefulness and adoption [17]. Consequently, potentially preventable nephrotoxic exposure and wrongful dosing continue to take their toll on the AKI progression and prolonged recovery of the kidney [18]. There are gaps in the renal-safe prescribing, to which a clinically-integrated supportive method with the ability to review renal parameters and medication profile continuously can help. The simplicity, transparency, and consistency with regular nephrology practice are key aspects that this approach needs to emphasise to facilitate its feasibility and acceptance in a critical care setting.

The primary objective of this study is to evaluate the association between an AI-assisted medication management approach and the appropriateness of renal dose adjustment in critically ill patients with acute kidney injury. Secondary objectives include assessment of AKI progression and renal recovery during intensive care admission. The investigation focuses on renal-specific outcomes and medication safety, positioning artificial intelligence as a supportive clinical tool rather than an autonomous decision-maker. Through emphasis on evidence-based renal care and conservative implementation, this study seeks to contribute clinically relevant data to the field of renal medicine and urinary system disorders.

Methods

Study Design and Setting

The study used a single-centre observational study design in an adult intensive care unit of a tertiary care hospital. It aimed to assess medication management practice in acute kidney injury patients in usual clinical care. There were no protocol-based interventions, experimental measures, or changes to the workflow. Every decision made in the management of the patients was made in accordance with the institutional policies and laid down guidelines of renal care. A supportive clinical tool was an AI-assisted medication review tool, but it did not change the prescribing authority. The trends in nephrology consultation and critical care did not change during the study period. This design enabled the evaluation of renal medication management in the real-world setting, which represents normal clinical practice that is common in the critical care nephrology unit.

Study Population

The eligibility was screened on adult patients in the intensive care unit within the stipulated period of the study. The inclusion criteria included an age of 18 years or older and a record of acute kidney injury that occurred during ICU admission. Kidney Disease: Improving Global Outcomes (KDIGO) criteria were used to diagnose acute kidney injury by assessing the variation in the serum creatinine levels and urine output measurements. The patients were involved regardless of the admitting diagnosis or the reason why they were admitted to the ICU. To be eligible, one had to receive at least one medication during the episode of AKI to be relevant to assessing renal medication safety. This strategy made sure that a heterogeneous population of critically ill patients, representative of a typical renal care practice, was included.

Exclusion Criteria

End-stage kidney disease patients undergoing maintenance renal replacement therapy before ICU admission were excluded because of constant dosing and pharmacokinetic changes. Patients who had a proven history of kidney transplantation could not be

included in the study since transplant-specific immunosuppressive and renal factors might confound medication evaluation. The patients who had missing renal laboratory records or lacked adequate records on their medication use were filtered out, as they might have affected the accuracy of renal dosing assessment. There were no exclusions according to the severity of the illness, duration of stay at the ICU, or comorbid conditions. The reduced exclusion approach was employed to maintain the representativeness of critically ill patients with acute kidney injury who were found in their normal practice in nephrology.

Renal Function Assessment

The evaluation of renal function was done on the basis of the regularly obtained clinical data, which included the serial measurements of serum creatinine and the documentation of urine output in the electronic medical record. Staging of acute kidney injury was based on KDIGO criteria in terms of absolute or relative changes in serum levels of creatinine and urinary output. The latest pre-admission serum creatinine was used to calculate baseline renal function when available. Where baseline assessment was not preceded by laboratory values, it was clinically interpreted as usual. The routine renal checks and the time interval were the typical forms of intensive care. No extra lab work or study-specific renal investigations were presented, as it was necessary to make it consistent with the real-life renal monitoring processes.

Medication Assessment

Medication evaluation consisted of all medications used within the reported case of acute kidney injury. Drugs were classified as renal eliminated or possibly nephrotoxic based on the existing nephrology resources and institutional prescribing guidelines. Dose appropriateness was assessed as compared against the modern renal functioning, AKI stage, and suggested renal dosing changes. The initiation, continued, interruption and alteration of medication in relation to the onset and progression of AKI were recorded. This method enabled them to assess renal-safe prescribing behaviours in the timeframe of altering renal functionality, which is typical in acutely ill patients with acute kidney damage.

AI-Assisted Medication Review

The artificial intelligence-supported system was used as a clinical decision support tool that aims to support renal-safe medication management. Serum creatinine values, urine output data and active medication orders accessed through the electronic medical record were taken as inputs. This system produced recommendations pertaining to renal dose alteration and diagnosis of possible nephrotoxic exposure. Clinician review and recommendations were shown manually, but not automated. Medication orders, prescription amendments, and clinical judgments were not triggered by the system. This clinician-in-the-loop model allowed artificial intelligence to play the role of a supportive tool but not to make final decisions regarding patients and medications under the existing clinical practice. The AI-assisted system was only used as a clinical decision support tool, and all the medication-related decisions were left at the discretion of the clinical practitioners who treated them.

Outcome Measures and Statistical Analysis

The main finding was the rate of correctly prescribed medications in relation to renal functional status in cases of acute kidney injury. AKI progression, which was the secondary outcome, was defined as further AKI worsening according to the KDIGO scale, and renal recovery, which was the next secondary outcome, was defined as the partial or total AKI resolution before ICU discharge. The demographic characteristics, renal parameters, and variables related to medication were summarised using descriptive statistics techniques. Categorical data were provided in the form of frequencies and percentages, and the mean or median values were used to summarise continuous variables accordingly. Where appropriate, a simple comparative analysis was used with a set statistical significance level.

Results

Clinical Profile and Baseline Renal Status

The target population was critically ill adult patients who were admitted with acute kidney injury to the intensive care unit. A majority of the patients were elderly individuals who had several comorbidities that were usually linked to renal vulnerability. The baseline renal status was different, with a significant percentage of patients showing impaired kidney functioning before going to the ICU. A high incidence of comorbid hypertension and diabetes was also common, which are the common risk factors of renal dysfunction. This patient group constitutes a risk group in relation to medication-induced kidney injury, and this clinical picture forms a suitable background for the assessment of renal-safe medication prescribing in the intensive care unit. Table 1 presents the baseline clinical comorbidities and renal function indicators, with a predominance of conditions associated with renal risk in critically ill patients.

Table 1: Baseline clinical and renal characteristics

Parameter	Mean / n	Percentage (%)
Age (years)	63 ± 12	-
Hypertension	71	61
Diabetes mellitus	48	41
Baseline eGFR <60 mL/min/1.73 m²	36	31

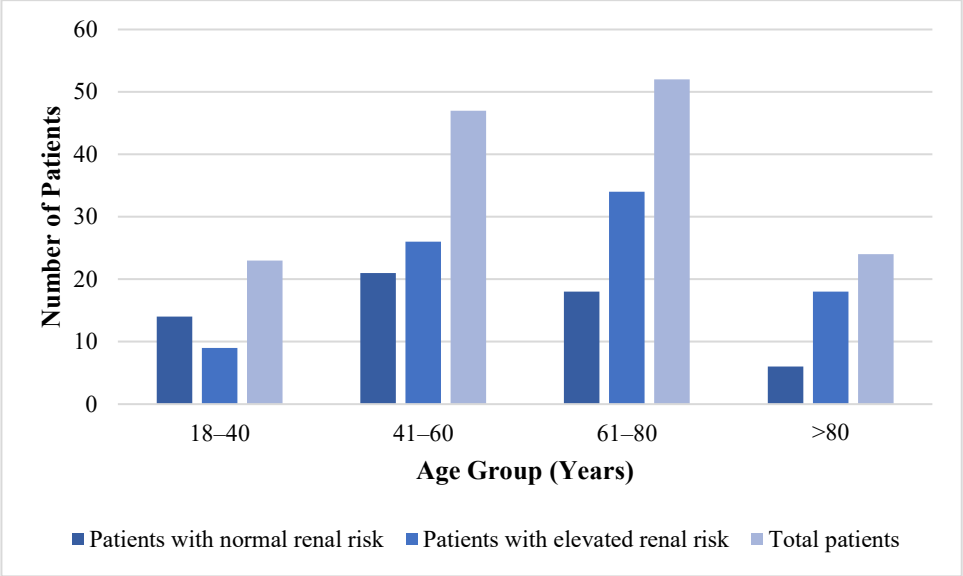

Figure 1: Age-wise Distribution of Renal Risk Categories Among Critically Ill Patients

Figure 1 shows the age-wise distribution of patients according to renal risk status, with a higher proportion of elevated renal risk observed in older age groups among critically ill patients.

Acute Kidney Injury Onset and Severity

Most of the patients had acute kidney injury that had been diagnosed early in the course of admission in the intensive care unit, and the onset of the acute kidney injury had happened in the initial days of the ICU stay. The classification based on the KDIGO criteria showed that early stages of AKI were mostly predominant, and the late stages were seen in a relatively low percentage. The severity of AKI distribution suggests uneven levels of renal dysfunction, which enables a measure of medication management across a range of renal dysfunction that is frequently present in critical care nephrology. Table 2 shows the time of onset of AKI in ICU admission and the severity of AKI as per KDIGO staging.

Table 2: Timing and severity of AKI

Parameter	Patients (n)	Percentage (%)
AKI onset ≤48 hours	62	53
AKI onset >48 hours	55	47
KDIGO stage 1-2	86	74
KDIGO stage 3	31	26

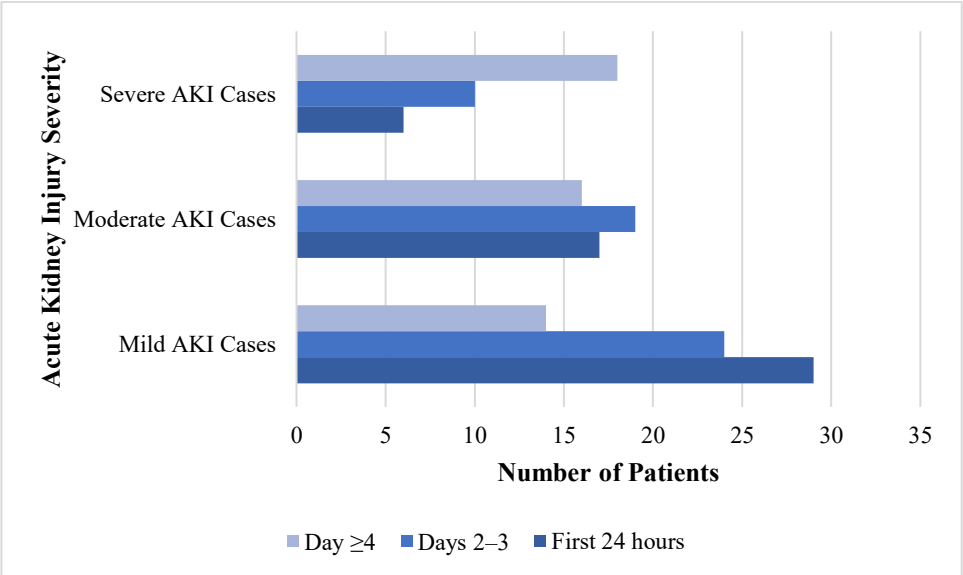

Figure 2: Timing of Acute Kidney Injury Onset Across Severity Categories

Figure 2 shows the distribution of mild, moderate, and severe acute kidney injury cases across different ICU timeframes. Early ICU admission is associated with a higher frequency of mild AKI, while severe AKI cases are more prominent in later ICU periods.

Medication Burden During Acute Kidney Injury

The complexity of critical care management was manifested by patients being under a variety of medications used during the cases of acute kidney injury. A significant percentage of the prescribed medications had to be renal dose adjusted because of renal elimination or nephrotoxicity. Polypharmacy was prevalent, which put them at risk of inappropriate dosing as renal function varied. Medication burden assessment gave an understanding of the issues in prescribing during AKI and underlined the need to perform a systematic renal medication review. Table 3 shows the level of medication exposure in acute kidney injury, drug burden and the use of nephrotoxic medications.

Table 3: Medication burden during AKI

Medication parameter	Mean / n	Percentage (%)
Total medications per patient	9 ± 3	-
Renally cleared drugs	6 ± 2	-
Patients receiving ≥1 nephrotoxic drug	78	67
High medication burden (≥10 drugs)	44	38

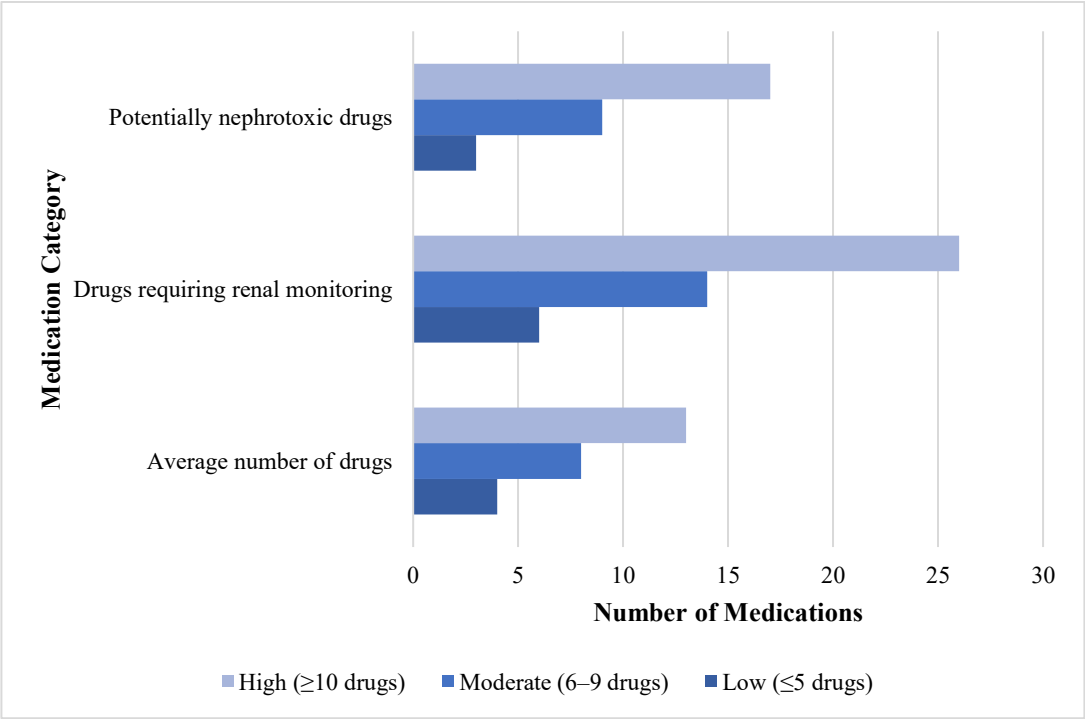

Figure 3: Medication Burden and Renal Risk During Acute Kidney Injury

Figure 3 shows that increasing medication burden during acute kidney injury is associated with a higher number of drugs requiring renal monitoring and greater exposure to potentially nephrotoxic agents, particularly in patients with high levels of polypharmacy.

Renal Dose Appropriateness and Review Findings

Determining the suitability of renal dose revealed inconsistency with dosing recommendations. Medications were not optimally adjusted to current renal functionality even before the advent of AI-assisted medication review. A greater percentage of drugs were reported to have been adjusted accordingly after the availability of AI-assisted review. The main improvements concerned the adjustment of the dose and the heightened awareness of the renal clearance needs during AKI. Table 4 shows the percentage of medications that were adjusted correctly to the renal functioning before and after the availability of AI-assisted medication review.

Table 4: Renal dose appropriateness of prescribed medications

Dosing status	Before review (%)	After review (%)
Appropriate for renal function	66	85
Not appropriate for renal function	34	15

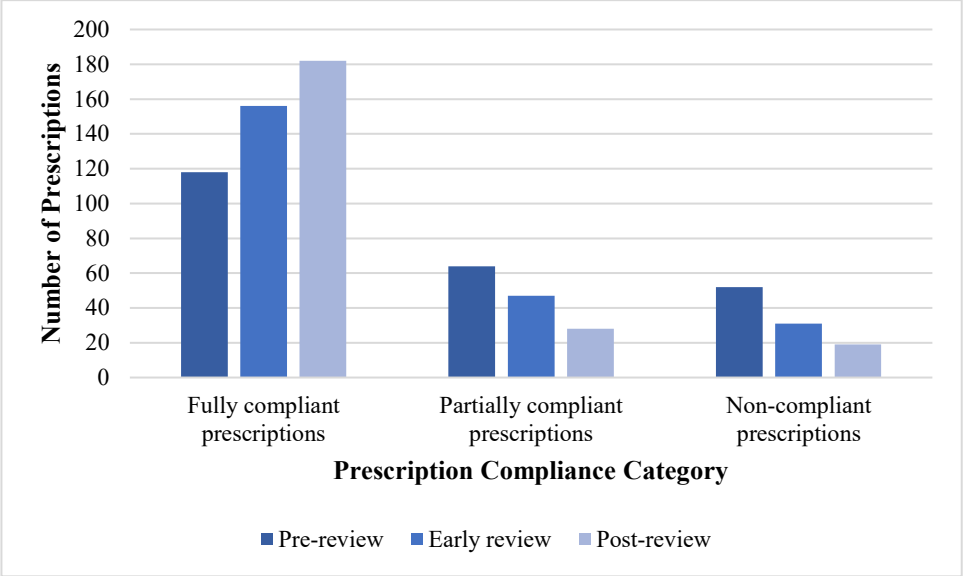

Figure 4: Changes in Renal Dose Compliance Across Medication Review Phases

Figure 4 shows a progressive increase in prescriptions optimally aligned with renal dosing recommendations and a corresponding reduction in partially compliant and non-compliant prescriptions across successive medication review phases.

Renal Function Trajectory During ICU Stay

The changes in renal functioning patterns under intensive care admission reported diverse results. Some percentage of the patients demonstrated some improvement in the renal parameters before discharging ICU, and some displayed renal impairment without further deterioration. A smaller group had deterioration in renal functioning, which was manifested by an increasing AKI stage. These findings demonstrate the dynamic process of renal recovery and progression in patients with critical illness and give clinical background to drug management in AKI. Table 5 shows the renal function patterns during intensive care admission, such as improvement, stability, and deterioration of kidney function.

Table 5: Renal function outcomes during ICU admission

Renal trajectory	Patients (n)	Percentage (%)
Improvement in renal function	51	44
Stable renal impairment	39	33
Worsening renal function	27	23

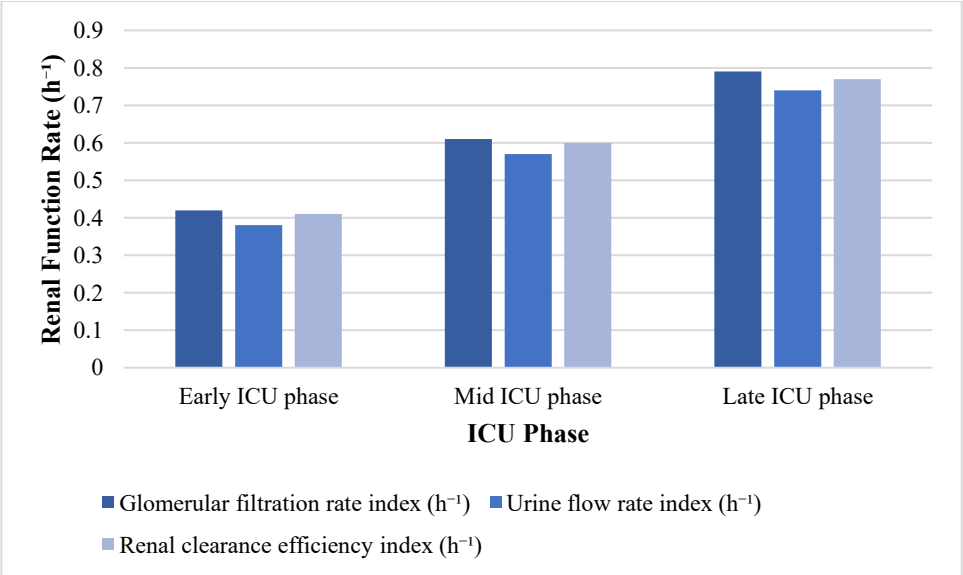

Figure 5: Trends in Renal Functional Indices During Intensive Care Stay

Figure 5 shows progressive improvement in glomerular filtration, urine flow, and renal clearance efficiency indices from early to late ICU phases, illustrating dynamic renal recovery patterns during critical illness.

Discussion

The study suggests the AI-supported medication review was significantly helpful in supporting renal-safe prescribing at acute kidney injury episodes in patients who were critically ill. The renal dose appropriateness is an indication of improved congruence between renal regimens and the rapidly fluctuating renal function, especially in a group with a high comorbidity burden, elderly age, and large polypharmacy. The identified rise in suitable dose modification implies that an ongoing consolidation of serum creatinine, urine output, and drug profiles aids in the earlier identification of renal clearance necessity and nephrotoxic danger. Significantly, this was accomplished regardless of the intricacy of care, as the patients were subjected to various renally eliminated and possibly nephrotoxic medications. The clinical picture of the renal functioning trends, where more patients show stabilisation and improvement rather than worsening, is encouraging. Although it is impossible to prove causality, the tendency is in line with reduced exposure to safer medications at risky stages of kidney damage. In general, the findings justify the conclusion that AI-supported review does not impair prescribing vigilance in AKI and does not interrupt the standard clinical procedure.

The recent scientific publications are reporting high levels of inappropriate renal dosing and preventable nephrotoxic exposure in the critically ill AKI patients. A study comparing traditional methods of prescribing drugs reports that there are always discrepancies in dose modification, especially in the initial stages or varying renal impairment [19]. The level of inappropriateness to dose observed in the current study is similar to the reports, and it provides support to the idea that manual practices are not always sufficient in the high-acuity setting [20]. In comparison to the conventional electronic alert systems that have been proven to be less effective than some other methods because of fixed thresholds and alert fatigue, approaches based on AI integration that are discussed in the recent literature focus on dynamic data incorporation and situational relevance [21]. The extent of the enhancement in renal dose appropriateness that was witnessed in this study is either comparable or higher than that recorded with conventional decision support tools, implying that there will be the potential add value [22]. In contrast to most predictive or black-box models reported in the recent literature, the supportive and transparent design adopted in this case is consistent with the new trends that advocate clinician-centred AI implementation. The study thus adds to and builds upon existing literature since it targets medication optimisation in established AKI as opposed to prediction.

The clinical importance of the present study is evident in the fact that the renal-safe prescribing can be enhanced by AI-assisted medication review without substituting clinician judgment in a real-life intensive care environment. Since medication-related errors and adverse renal outcomes are closely related, even the small changes in the appropriateness of dose may lead to significant decreases in AKI progression, complications in treatment, and healthcare utilisation. Nevertheless, there are a number of constraints that should be taken into consideration. The single-centre observational study design does not allow generalisation and does not allow causal inferences. Enhancement of prescribing behaviour could have been positively affected by increased clinical awareness as opposed to the AI system itself. The outcomes of renal recovery were measured at the admission stage of the ICU, and the outcomes were not followed up in the long term to determine long-term renal functioning or chronic kidney disease development. Also, there was no complete adjustment of the severity of illness and non-medication-related factors on renal outcomes, which could confound the interpretation of renal trajectories. Regardless of these limitations, the study is representative of the common clinical practice and offers realistic information regarding the way AI tools can be used in real-life, which contributes to its increased practical significance.

The main goal of assessing the correlation of AI-aided medication management and renal dose appropriateness was directly met, and the results showed a better prescription-renal function fit. The secondary goals based on AKI progression and renal salvaging were also informed by observed renal curves in ICU stay, which provide contextual data of how safer medication management can lead to more desirable renal outcomes. The study has focused on supporting a clinician-in-the-loop model as opposed to independent decision-making and achieved its goal of aligning artificial intelligence with its objective of complementing normal nephrology practice, but not eliminating it. Altogether, the discussion supports the assumption that AI-assisted medication review is a viable and clinically meaningful approach to resolving the long-standing issues of renal-safe prescribing in acute kidney injury.

Future studies must involve multicentric, prospective study designs, which should confirm the impact of AI-assisted medication management in various critical care environments and groups of patients. Longer follow-up periods should be included to measure long-term recovery of the renal situation, the necessity of renal replacement therapy, and the development of chronic kidney disease. Given that the current state of AI systems is not yet advanced enough to include severity-of-illness scores, hemodynamic parameters, or cumulative nephrotoxic exposure, further refinement will help increase the clinical relevance and accuracy. Further, clinician acceptance, integration of workflow, and cost-efficiency will also be critical to further implementation. With the ongoing development of artificial intelligence, the focus on transparency, interpretability, and clinician supervision will be important to making sure that these kinds of tools can be used to promote safe, ethical, and patient-centred renal care.

Conclusions

The study has shown that AI-assisted medicine review is capable of beneficially contributing to the first aim, which is to enhance renal-safe prescribing in acutely ill patients with acute kidney injury. The AI-assisted solution provided an opportunity to overcome one of the

main modifiable risk factors associated with AKI development in intensive care units, as it facilitated the identification of renal dosing needs as well as the possibility of nephrotoxic exposure promptly. The results suggest that reconsiderable, renal-centred prescribing review is especially beneficial to all settings with heavy-medication loads, high rates of physiological variability, and scarce possibilities of manual review. Notably, the AI was used as a supportive clinical aid and not as a substitute for the judgment of the clinicians, which also fits the purpose of the study to retain the normal practice of nephrology and improve the decision-making. The fact that better dosing appropriateness and better renal trajectories during ICU admission were observed supports the clinical relevance of the integration of such tools in the routine care. On balance, the study contributes to the potential practicality of transparent, clinician-centred AI applications as one of the instruments to enhance medication safety and improve renal management in critically ill patients during acute kidney injury.

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