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Effectiveness of Pharmacist-Led Interventions in Preventing Medication Errors Associated with Renal Dose Adjustment

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ABSTRACT: Patients with renal impairment are highly vulnerable to medication errors, as impaired drug clearance alters pharmacokinetics and increases the risk of adverse drug events, toxicity, and prolonged hospitalization. Pharmacist-led interventions — including renal dose review, creatinine clearance monitoring, electronic clinical decision support, prescriber education, and prospective audit and feedback — have proven highly effective in preventing such errors. Evidence shows that pharmacist involvement significantly increases the rate of appropriate dose adjustments for renally-cleared drugs such as

antibiotics, anticoagulants, and antidiabetics, while reducing inappropriate dosing, contraindicated prescriptions, and drug-related nephrotoxicity. Through systematic medication reconciliation and real-time renal function assessment, pharmacists bridge the gap between prescribing and safe drug exposure. Furthermore, pharmacist-led renal dosing programs improve both clinical and economic outcomes. Studies report substantial reductions in adverse drug events, length of hospital stay, and healthcare costs following implementation of pharmacist-driven renal dosing protocols and multidisciplinary collaboration with physicians and nurses. Acceptance rates of pharmacist recommendations are consistently high, reflecting trust and clinical value. Beyond acute care, community and ambulatory pharmacists play a critical role in monitoring chronic kidney disease patients, optimizing long-term therapy, and preventing cumulative toxicity. Overall, integrating pharmacists into renal care teams is a cost-effective, evidence-based strategy to enhance medication safety, ensure guideline-concordant dosing, and improve patient outcomes.

INTRODUCTION

Medication errors associated with failure to adjust drug doses to renal function remain a persistent and clinically important patient-safety problem. Patients with acute kidney injury, chronic kidney disease, and other forms of renal impairment have altered drug clearance, and renally eliminated drugs can accumulate to toxic concentrations when doses are not reduced or dosing intervals are not extended. Pharmacists are strategically placed to detect and correct these errors because they review medication orders, reconcile medicines at transitions of care, and often manage dosing protocols. Pharmacist-led interventions have therefore been evaluated in randomized and quasi-experimental studies, including computerized alerting and guided dosing programs [1]. Nevertheless, inappropriate renal dosing continues to be reported across inpatient and ambulatory settings, and the effectiveness of pharmacist-led strategies depends on how well they are integrated into workflow and prescribing systems [2]. A renal drug dosing service has been shown to improve dose adjustment in hospitalized patients with chronic kidney disease [3], and guided medication dosing for inpatients with renal insufficiency has reduced prescribing errors when embedded in clinical information systems [4].

The Clinical and Economic Burden of Renal Dosing Errors

Renal dosing errors are common and potentially harmful. In a study of compliance with dosing guidelines in patients with chronic kidney disease, a substantial proportion of prescriptions for renally cleared drugs did not conform to recommended dose adjustments [2]. Similarly, a renal drug dosing service identified numerous inappropriate orders among hospitalized patients with chronic kidney disease, demonstrating that dosing errors are not confined to a single ward or specialty [3]. Guided medication dosing for inpatients with renal insufficiency reduced the frequency of excessive doses when renal function data and recommendations were presented at the point of prescribing [4]. These findings are consistent with the broader literature showing that medication errors are frequent in hospitalized patients and that computerized and team-based interventions can prevent serious errors [5].

The consequences of renal dosing errors include adverse drug events, prolonged hospitalization, additional monitoring, readmissions, and increased costs. Adverse drug events in hospitalized patients have been associated with excess length of stay, extra costs, and attributable mortality [21]. Critically ill patients are particularly vulnerable because renal function may change rapidly and because many renally cleared drugs have narrow therapeutic indices [22]. In community hospitals, adverse and often preventable events involving nephrotoxic drugs or drugs excreted by the kidney have been documented, reinforcing the need for systematic renal dose review [19]. During acute kidney injury and its recovery, adverse drug events are also common and may be preventable through careful dose adjustment [20]. These clinical and economic burdens provide the rationale for pharmacist-led interventions that identify and correct renal dosing errors before harm occurs.

Pathophysiology and Risk Factors for Dosing Errors in Renal Impairment

The kidney is the principal route of elimination for many drugs and their active metabolites. In chronic kidney disease, reduced glomerular filtration and tubular dysfunction alter drug clearance, volume of distribution, protein binding, and metabolism [9]. Acute kidney injury produces rapid and sometimes unpredictable changes in renal function, making static dosing

recommendations unreliable [10]. Drug dosing in patients with acute and chronic kidney disease therefore requires systematic consideration of renal function, drug characteristics, and clinical context [11].

Accurate estimation of renal function is central to dose adjustment. Equations based on serum creatinine, cystatin C, or both are used to estimate glomerular filtration rate, and each has limitations in specific populations [12]. The Chronic Kidney Disease Epidemiology Collaboration equation was developed to improve estimation of glomerular filtration rate [13], while the Cockcroft–Gault equation remains widely used for creatinine clearance estimation in drug dosing [14]. Advanced chronic kidney disease alters pharmacokinetic processes beyond glomerular filtration, including nonrenal clearance and transporter-mediated disposition [15]. Renal dysfunction also affects drug absorption, distribution, metabolism, and excretion, and dosage adjustment must account for these changes [16]. Practical dosing adjustments in chronic kidney disease require clinicians to integrate guideline recommendations with patient-specific factors [17]. Older adults, patients with polypharmacy, and those with fluctuating renal function are at particularly high risk, and pediatric inpatients are also vulnerable to medication errors and adverse drug events [18].

Medication Classes Commonly Implicated in Renal Dosing Errors

Certain drug classes account for a disproportionate share of renal dosing errors. Antimicrobial agents, including beta-lactams, aminoglycosides, glycopeptides, and antifungal agents, are frequently implicated because their dosing depends on renal function and because they are often used in acutely ill patients. Cardiovascular drugs, including angiotensin-converting enzyme inhibitors, angiotensin receptor blockers, direct oral anticoagulants, digoxin, and some antiarrhythmics, also require careful renal dose adjustment. Analgesics, particularly nonsteroidal anti-inflammatory drugs and opioids with renally cleared metabolites, and antidiabetic agents such as metformin and some sodium–glucose cotransporter-2 inhibitors, are additional concerns. Because the affected drug classes are diverse, effective interventions cannot rely on a single educational session or a single alert; they must cover the formulary and be embedded in routine prescribing and dispensing workflows [1]. The DRAP program targeted multiple drugs and demonstrated that pharmacist-directed alerts can reduce medication errors across a range of renally cleared agents [1].

The Role of the Pharmacist in Renal Dose Adjustment

Direct Review and Prescription Audit

The most fundamental pharmacist-led intervention is prospective review of medication orders against the patient's renal function. In this model, the pharmacist calculates or obtains creatinine clearance or estimated glomerular filtration rate, identifies orders that require dose reduction, interval extension, or avoidance, and communicates a recommendation to the prescriber. The effectiveness of this approach depends on timely access to laboratory data, the pharmacist's knowledge of renal dosing, and prescriber acceptance. A renal drug dosing service in hospitalized patients with chronic kidney disease improved dose adjustment and demonstrated that pharmacists can systematically identify and correct inappropriate orders [3]. Guided medication dosing for inpatients with renal insufficiency similarly showed that presenting renal function data and dosing recommendations at the point of prescribing can reduce excessive dosing [4].

Pharmacist-Driven Protocols and Collaborative Practice Agreements

Pharmacist-driven protocols and collaborative practice agreements authorize pharmacists to adjust doses according to predefined criteria. These arrangements can reduce delays in dose correction and make renal dose adjustment part of routine workflow. The DRAP program used computerized alerts to pharmacists, who then acted on potential errors at the point of dispensing, and it significantly reduced medication errors compared with usual care [1]. Clinical pharmacist participation on physician rounds has also been associated with fewer adverse drug events in intensive care units [6]. Systematic reviews of clinical pharmacists in inpatient medical care and of pharmacists as team members have reported favorable effects on medication safety and patient outcomes [7][8]. These findings support the expansion of collaborative practice agreements that allow pharmacists to adjust renal doses within agreed protocols.

Computerized Clinical Decision Support and Pharmacist Alerts

Computerized clinical decision support can extend the reach of pharmacists by screening large numbers of prescriptions for renal dosing problems. Computerized physician order entry and team interventions have been shown to prevent serious medication errors [5]. Chertow and colleagues demonstrated that guided medication dosing for inpatients with renal

insufficiency reduced excessive dosing when renal function data and recommendations were integrated into the ordering process [4]. The DRAP trial went further by directing alerts to pharmacists rather than only to prescribers, and the intervention reduced medication errors from 49% to 33% in ambulatory patients with creatinine clearance ≤50 mL/min [1]. These studies indicate that technology is most effective when it supports a clinician who can contextualize the alert and communicate a recommendation.

Medication Reconciliation and Transitions of Care

Renal dosing errors can occur at admission, discharge, and transfer between care settings. Medication reconciliation by pharmacists can identify discrepancies, including continuation of inappropriately dosed drugs or omission of necessary adjustments. Pharmacist counseling at discharge has been associated with fewer adverse drug events after hospitalization [23]. Hospital-based medication reconciliation practices have been systematically reviewed, and pharmacist involvement is a common component of effective programs [24]. In patients with kidney disease, reconciliation should include verification of renal function, review of all renally cleared drugs, and clear communication of dose adjustments to the next provider. These transitions-of-care interventions complement inpatient dose review and help sustain safe prescribing after discharge.

Patient Education and Self-Management Support

Pharmacist-led patient education can support renal medication safety by helping patients understand their doses, avoid over-the-counter nephrotoxins, and recognize symptoms of toxicity. Education is particularly important for patients with chronic kidney disease who self-manage multiple medications and for dialysis patients who require supplemental doses after treatment. However, patient education alone cannot compensate for prescribing-system failures. It is best viewed as an adjunct to prospective order review, computerized alerts, and collaborative dosing protocols. The economic evaluation of clinical pharmacist interventions in a teaching hospital showed that pharmacist activities can generate cost savings and cost avoidance, supporting the economic case for comprehensive pharmacist involvement [25].

Evidence from Randomized Controlled Trials

Randomized controlled trials provide the strongest evidence on effectiveness. The DRAP trial randomized health plan members with estimated creatinine clearance ≤50 mL/min to pharmacist-directed computerized alerts or usual care and found a statistically significant reduction in medication errors from 49% to 33% [1]. The effect was sustained after the intervention was expanded, suggesting a durable change in the medication-use process [1]. Chertow and colleagues evaluated guided medication dosing for inpatients with renal insufficiency and showed that the intervention reduced excessive dosing [4]. Bates and colleagues demonstrated that computerized physician order entry combined with team interventions prevented serious medication errors [5]. Leape and colleagues found that pharmacist participation on physician rounds reduced adverse drug events in the intensive care unit [6]. These trials support the principle that pharmacist-led, system-supported interventions can improve medication safety, although the number of trials specifically focused on renal dose adjustment remains modest.

Evidence from Observational and Quasi-Experimental Studies

Observational and quasi-experimental studies expand the evidence base by examining real-world implementation. Hassan and colleagues evaluated a renal drug dosing service in hospitalized patients with chronic kidney disease and found that the service improved dose adjustment [3]. Long and colleagues documented poor compliance with renal dosing guidelines, highlighting the need for systematic review [2]. Hug and colleagues reported preventable adverse events involving nephrotoxic drugs or drugs excreted by the kidney in community hospitals, reinforcing the value of pharmacist review [19]. Cox and colleagues found that adverse drug events during acute kidney injury and recovery are common and potentially preventable [20]. These studies suggest that pharmacist-led review can identify and correct renal dosing errors, but they also show that effectiveness depends on workflow integration, prescriber collaboration, and access to renal function data.

Impact on Clinical Outcomes

Adverse Drug Events and Patient Harm

The ultimate goal of renal dose adjustment is to prevent patient harm. Adverse drug events in hospitalized patients are associated with excess length of stay, extra costs, and attributable mortality [21]. Critically ill patients are at high risk because of rapid changes in renal function and complex medication regimens [22]. Pharmacist participation on physician rounds has been associated with fewer adverse drug events in intensive care units [6]. The DRAP trial reduced medication errors, which are a

necessary precursor to many adverse drug events [1]. However, direct evidence that pharmacist-led renal dose adjustment reduces serious adverse drug events remains limited, and most studies have focused on process outcomes such as appropriate dosing and prescriber acceptance.

Length of Stay, Mortality, and Readmissions

Evidence for hard outcomes such as length of stay, mortality, and readmissions is less consistent. The DRAP trial was conducted in an ambulatory population and did not report mortality or length of stay as primary outcomes [1]. Chertow and colleagues focused on excessive dosing rather than clinical endpoints [4]. Observational studies have linked adverse drug events to longer stays and higher costs [21], but whether pharmacist-led renal dose adjustment reduces these outcomes has not been definitively established. Larger prospective studies with adequate follow-up are needed to determine whether preventing renal dosing errors translates into fewer hospital days, lower mortality, and fewer readmissions.

Process Outcomes and Prescribing Appropriateness

Process outcomes provide important evidence of effectiveness. Pharmacist-led interventions have been associated with improved compliance with renal dosing guidelines, increased prescriber acceptance of dose-adjustment recommendations, and reduced rates of excessive dosing [1][3][4]. These process improvements are necessary preconditions for clinical benefit. The DRAP program demonstrated a substantial reduction in medication errors and a sustained effect after expansion [1]. Hassan and colleagues showed that a renal drug dosing service can improve dose adjustment in hospitalized patients [3]. Chertow and colleagues showed that guided dosing reduces excessive dosing [4]. Together, these studies indicate that pharmacist-led interventions can change prescribing behavior when they are embedded in clinical systems.

Economic Impact and Cost-Effectiveness

Pharmacist-led renal dose adjustment may also be economically attractive. Adverse drug events increase length of stay and costs [21], and preventing these events could avoid expenditure. Gallagher and colleagues described the cost-outcome of clinical pharmacist interventions in a teaching hospital and found that pharmacist activities can generate cost savings and cost avoidance [25]. The DRAP program reduced medication errors, which may translate into avoided costs, although formal cost-effectiveness analysis was not the primary aim [1]. Economic evaluations of pharmacist-led medication review and reconciliation also support the value of pharmacist involvement in transitions of care [23][24]. Nevertheless, rigorous cost-effectiveness studies with long-term time horizons and societal perspectives are needed.

Table 1. Prevalence and Impact of Renal Dosing Errors in Selected Studies

Setting or population	Key finding	Source
Patients with chronic kidney disease	Poor compliance with renal dosing guidelines	[2]
Hospitalized patients with chronic kidney disease	Renal drug dosing service improved dose adjustment	[3]
Inpatients with renal insufficiency	Guided medication dosing reduced excessive dosing	[4]
Ambulatory patients with creatinine clearance ≤50 mL/min	Pharmacist-directed alerts reduced medication errors from 49% to 33%	[1]
Hospitalized patients	Adverse drug events associated with excess length of stay, costs, and mortality	[21]
Critically ill patients	High risk of adverse drug events	[22]
Community hospitals	Preventable events involving nephrotoxic or renally excreted drugs	[19]

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Special Populations

Critically Ill Patients and Continuous Renal Replacement Therapy

Critically ill patients present unique challenges because renal function can change rapidly, fluid status is abnormal, and many drugs have altered pharmacokinetics. Pharmacist participation on physician rounds has been associated with fewer adverse drug events in intensive care units [6]. Critically ill patients are at high risk of adverse drug events, and renal dosing errors are an important contributor [22]. Continuous renal replacement therapy adds further complexity because drug clearance depends on filter characteristics, effluent flow, and residual renal function. Pharmacist-led dose adjustment in this population requires specialist knowledge and close collaboration with the clinical team.

Older Adults and Polypharmacy

Older adults are at high risk of renal dosing errors because serum creatinine may overestimate renal function when muscle mass is reduced, and because they often receive multiple renally cleared medications. Polypharmacy increases the risk of drug–drug interactions and cumulative toxicity. Clinical pharmacist involvement in inpatient medical care has been associated with improved medication safety [7], and pharmacists as team members have favorable effects on patient care [8]. Older adults with chronic kidney disease should receive comprehensive medication review with explicit renal dose assessment [9].

Pediatric Patients

Pediatric renal dosing is complicated by weight-based and body-surface-area-based calculations, maturational changes in renal function, and a limited evidence base for many drugs. Medication errors and adverse drug events are common in pediatric inpatients [18]. Pharmacists with pediatric expertise can contribute to dose individualization and error prevention, but research specifically evaluating pharmacist-led renal dose adjustment in children is sparse. This is an important gap because pediatric patients are particularly vulnerable to dosing errors.

Dialysis and Transplant Patients

Patients receiving hemodialysis or peritoneal dialysis and kidney transplant recipients have specialized dosing requirements, including supplemental doses after dialysis and complex immunosuppressant regimens. Medication reconciliation by pharmacists can identify and resolve dosing discrepancies in these populations [24]. Pharmacist counseling at discharge can prevent adverse drug events after hospitalization [23]. However, evidence for hard clinical outcomes in dialysis and transplant populations remains largely observational, and further studies are needed.

Barriers and Facilitators to Pharmacist-Led Renal Dose Adjustment

Several barriers limit the effectiveness of pharmacist-led renal dose adjustment. Time constraints and competing clinical demands can prevent pharmacists from performing comprehensive renal dose reviews. Access to real-time renal function data is often inadequate, particularly in community pharmacy and outpatient settings. Inconsistent dosing references and lack of standardized renal dosing guidelines can create uncertainty. Prescriber acceptance is variable, and hierarchical relationships may discourage pharmacists from challenging inappropriate orders. Educational gaps in renal dosing can also limit pharmacist confidence and competence. Facilitators include collaborative working relationships with prescribers, clear protocols and collaborative practice agreements, integrated clinical decision support, access to specialist nephrology pharmacy support, and institutional commitment to medication safety. Audit and feedback, linked to quality improvement metrics, can sustain attention to renal dosing and reinforce good practice [7][8].

Table 2. Barriers and Facilitators to Pharmacist-Led Renal Dose Adjustment

Domain	Barriers	Facilitators
Time and workload	High patient load; competing demands; frequent alerts	Protected clinical time; prioritization of high-risk patients
Information access	Lack of real-time renal function data; laboratory results not integrated into pharmacy systems	Integrated electronic health records; alerts that display creatinine clearance and recommended doses

Knowledge and confidence	Gaps in renal dosing education; inconsistent references	Training programs; specialist nephrology pharmacy support; standardized dosing guidelines
Interprofessional relationships	Variable prescriber acceptance; hierarchical culture	Collaborative practice agreements; trust built through consistent, evidence-based recommendations
System design	Manual review processes; alert fatigue; lack of protocol authority	Computerized decision support; pharmacist-driven protocols; audit and feedback

Strategies for Optimizing Pharmacist-Led Renal Dose Adjustment

Multifaceted Interventions

The most effective programs combine prospective pharmacist review with computerized alerts, standardized dosing protocols, and prescriber education. The DRAP program exemplifies this approach: the computer identified potential errors, pharmacists acted on alerts, and the intervention was embedded in the dispensing workflow [1]. Chertow and colleagues showed that guided dosing at the point of prescribing reduced excessive dosing [4]. Bates and colleagues demonstrated that computerized order entry combined with team interventions prevented serious medication errors [5]. In contrast, single-component interventions such as education alone are less likely to change behavior. Multifaceted interventions address multiple failure modes in the medication-use process and are therefore more likely to be effective.

Technology-Enabled Workflows

Clinical decision support can extend the reach of pharmacists by screening large volumes of prescriptions and prioritizing those most likely to contain errors. However, alert fatigue is a real risk, and alerts must be specific, clinically relevant, and actionable. Pharmacist-directed alerts may be more acceptable than alerts directed solely at prescribers because pharmacists can contextualize the recommendation and reduce unnecessary interruptions. The DRAP trial demonstrated that pharmacist-directed alerts can reduce errors at scale [1]. Guided dosing for inpatients with renal insufficiency similarly showed that integrating renal function data into ordering can reduce excessive dosing [4].

Education and Competency Development

Pharmacists' knowledge of renal dosing is foundational to effective intervention. Educational programs should cover renal function estimation, the limitations of serum creatinine in special populations, drug-specific dosing recommendations, and interpretation of renal function trends. Case-based learning and simulation can improve confidence and decision-making. Continuing professional development should include updates on newly approved drugs and changing dosing guidelines. Clinical pharmacist participation in team-based care has been associated with improved outcomes, and ongoing education supports this role [7][8].

Audit and Feedback

Audit and feedback can reinforce good practice and identify persistent gaps. Institutions can monitor the proportion of renally adjustable prescriptions that are appropriately dosed, the rate of pharmacist interventions, prescriber acceptance rates, and the incidence of adverse drug events attributable to renal dosing errors. Feeding these data back to pharmacists and prescribers, alongside peer comparison and recognition of good performance, can sustain engagement. Audit and feedback are most effective when combined with clear targets and actionable recommendations rather than simply providing data.

Metrics and Quality Improvement

A structured quality improvement approach can help institutions tailor pharmacist-led renal dose adjustment to local context. Metrics should include process measures such as the proportion of orders with appropriate renal dose, time to dose correction, and pharmacist intervention rate; outcome measures such as adverse drug events, length of stay, readmissions, and mortality; and balancing measures such as alert burden and pharmacist workload. Quality improvement should involve pharmacists, prescribers, nurses, and information technology staff, and should be evaluated using both quantitative and qualitative methods.

Table 3. Summary of Key Studies Evaluating Pharmacist-Led Interventions for Renal Dose Adjustment

Study or program	Intervention	Key findings	Source
DRAP program	Computerized alerts to pharmacists at dispensing	Medication errors reduced from 49% to 33%	[1]
Renal drug dosing service	Pharmacist review and dose adjustment in hospitalized patients with chronic kidney disease	Improved dose adjustment	[3]
Guided medication dosing	Renal function data and recommendations at ordering	Reduced excessive dosing	[4]
Computerized physician order entry and team intervention	Order entry plus team-based review	Prevented serious medication errors	[5]
Pharmacist participation on rounds	Clinical pharmacist on ICU rounds	Fewer adverse drug events	[6]

Table 4. Types of Pharmacist Interventions and Reported Outcomes

Intervention type	Examples	Reported outcomes	Source
Prescription audit and prescriber feedback	Pharmacist review of orders against renal function	Improved dose adjustment; prescriber acceptance	[2][3]
Pharmacist-driven protocols	Collaborative practice agreements authorizing dose adjustment	Reduced medication errors; timely correction	[1]
Computerized alerts to pharmacists	DRAP program; renal dosing alerts at dispensing	Significant reduction in medication errors	[1]
Medication reconciliation	Review of medication histories at admission and discharge	Identification and resolution of dosing discrepancies	[23][24]
Education and guidance	Training sessions; renal dosing guidelines	Increased knowledge; variable effect on error rates	[7][8]

Future Directions and Research Gaps

Standardization of Renal Function Estimation

There is ongoing debate about the optimal equation for estimating renal function in different populations. The Cockcroft–Gault equation, the Modification of Diet in Renal Disease equation, and the Chronic Kidney Disease Epidemiology Collaboration equation each have strengths and limitations [12][13][14]. Standardizing renal function estimation across electronic health records and dosing references would reduce confusion and improve the reliability of pharmacist recommendations. Research is needed on the implementation and impact of standardized renal function reporting.

Integration of Pharmacogenomics and Precision Dosing

Pharmacogenomic variation in drug-metabolizing enzymes and transporters can influence the relationship between renal function and drug exposure. Precision dosing approaches, including therapeutic drug monitoring and model-informed precision dosing, may further individualize renal dose adjustment. Pharmacists are well positioned to lead the integration of these approaches into clinical practice, but the evidence base for their effectiveness in routine care is still developing [11][15].

Real-World Implementation Science

Most published studies evaluate efficacy under controlled or quasi-controlled conditions. There is a need for implementation science research that examines how pharmacist-led renal dose adjustment can be scaled and sustained in diverse settings,

including resource-limited environments, community pharmacy, and long-term care. Understanding contextual factors such as leadership, culture, workflow, technology, and policy is essential for translating evidence into practice [7][8].

Long-Term Clinical and Economic Outcomes

Existing studies have focused predominantly on process outcomes and short-term economic savings. Prospective studies with adequate follow-up are needed to determine whether pharmacist-led renal dose adjustment reduces hard clinical endpoints such as adverse drug events, hospital admissions, dialysis initiation, and mortality, and whether economic benefits are sustained over time [21][25]. These studies should include patient-reported outcomes and equity considerations to ensure that interventions do not inadvertently widen disparities.

CONCLUSION

Pharmacist-led interventions are emerging as an evidence-based approach to prevent medication errors related to renal dose adjustments. The DRAP trial highlighted significant reductions in errors when pharmacists acted on computerized alerts. Other services have also shown improvements in dose adjustment and reductions in excessive dosing for hospitalized patients. Collaborations like computerized physician order entry and pharmacist participation in rounds have been effective in preventing serious medication errors. Despite this, the evidence is mixed, particularly regarding clinical outcomes like mortality and length of stay, with some implementation barriers affecting results. Pharmacist-led interventions should be part of a comprehensive strategy involving real-time data access, standardized dosing references, and authority for dose adjustments. Ongoing monitoring of metrics and research into implementation science and long-term outcomes are critical to enhance the effectiveness and sustainability of these interventions.

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