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Impact of an inpatient pharmacist-driven renal dosing policy on order verification time and patient safety

Kayla Berry[1], Laura Postlmayr[2], Dane Shiltz[3,5], Jessi Parker[4] and Calvin Ice[5]

Abstract

Research regarding pharmacist-driven renal dosing policies has focused on cost savings or prevention of adverse drug events. However, little is known about how these policies influence time from order signature to order verification or how this efficiency may reduce the incidence of adverse outcomes. **Objectives:** The primary endpoint compared time from prescriber electronic order signature to pharmacist electronic order verification between pre- and post-renal dosing policy implementation. The secondary endpoint evaluated electrocardiogram QTc prolongation attributed to fluconazole accumulation in renal impairment. **Methods:** This retrospective analysis included adults with a creatine clearance ⩽50 mL/min who received at least two inpatient doses from a 34-medication renal dosing protocol between January–February 2020 and April–May 2020. **Results:** 502 patients met eligibility for the primary outcome. The pre- and post-policy cohorts shared similar baseline characteristics. Time from order signature to verification was 9 and 8 min in the pre- and post-policy groups, respectively ($p = 0.0861$). In all, 56 patients met inclusion criteria for the secondary outcome. The QTc interval during fluconazole increased relative to baseline in 3 of 7 (43%) pre-policy and 4 of 5 (80%) post-policy. The QTc interval exceeded 500 ms in two patients, both in the post-policy cohort. **Conclusions:** There was no difference in order signature to verification time. Post-policy fluconazole renal adjustment did not reduce QTc prolongation.

Keywords

Drug dosing, protocol, pharmacist, QTc prolongation, medication safety, fluconazole

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Introduction

Health systems have implemented medication dosing protocols to standardize practice processes and to improve the quality of patient care. One established example involves inpatient pharmacist-driven renal dosing protocols. Pharmacists monitor patient renal function and utilize institution-specific pharmacy and therapeutics (P&T)-approved protocols to assist with appropriate dosage adjustments in the setting of acute or chronic renal impairment to avoid over- and under-dosing in the setting of fluctuating renal clearance. Renal dosing services can potentially minimize medication toxicity, reduce nursing workload, and reduce medication-associated health system expenses.[1] Policies that support pharmacist-enabled renal dosing protocols are partly derived from research that reveals prescriber nonadherence to appropriate drug dosing in renal impairment ranges from 19% to 67%.[1,2] The primary reasons for inappropriate dosing primarily result from limited knowledge about a specific drug or lack of information about the patient's renal function at the time of prescribing.[1,2] One study revealed that among 202 medication regimens, 75% included at least one inappropriate prescription relative to the individual renal impairment severity, thereby potentiating the risk for patient harm.[3]

[1]Michigan Medicine, University of Michigan Health, Ann Arbor, MI, USA
[2]Sinai-Grace Hospital—Detroit Medical Center, Detroit, MI, USA
[3]College of Pharmacy, Ferris State University, Grand Rapids, MI, USA
[4]Scholarly Activity and Scientific Support Spectrum Health, Grand Rapids, MI, USA
[5]Butterworth Hospital Pharmacy, Spectrum Health, Grand Rapids, MI, USA

Corresponding author:
Dane Shiltz, College of Pharmacy, Ferris State University, Suite 7000, 25 Michigan Street NE, Grand Rapids, MI 49503, USA.
Email: DaneShiltz@ferris.edu

Multiple studies have demonstrated that patients experiencing renal impairment are at risk for suboptimal dosing.[1–4] One retrospective observational study assessed the accuracy of drug dosing and its frequency in patients with renal impairment.[4] The study identified that among 1338 medications reviewed, 180 (13%) required renal dose adjustment; however, only 34 (19%) of these were adjusted appropriately. Pharmacists' patient care responsibilities regularly consist of reviewing patient charts to identify medications eligible for renal dosing adjustments. When collaborative drug therapy management (CDTM) agreements that empower pharmacists to make autonomous renal dosing adjustments without initial prescriber review do not exist, pharmacists must contact prescribers for approval prior to these interventions. CDTM agreements permit pharmacists to efficiently make changes to prespecified medications in the setting of renal impairment without contacting prescribers,[5] potentially saving pharmacist time, minimizing prescriber interruption, and reducing the likelihood of a dose-related adverse event due to drug accumulation in the setting of renal impairment.[6,7] CDTM agreements further streamline pharmacist-driven medication dose and/or frequency updates.[5] Despite the projected and theoretical advantages, little remains known about whether CDTM agreements reduce order entry time or renal impairment-associated adverse drug events. Since reductions in order verification time and adverse drug events can each potentially reduce healthcare expenditures, evaluation of these endpoints is prudent.

The following retrospective observational study evaluated the time from prescriber electronic medication order signature to pharmacist order verification pre- and post-implementation of an inpatient renal dosing policy approved to facilitate appropriate dosing in the setting of varying degrees of renal impairment and treatment diagnosis when dosing variation existed by therapeutic indication. The secondary outcome compared the same pre-policy to the post-policy periods for the incidence of QTc prolongation attributed to fluconazole accumulation in renal impairment.

Methods

This retrospective study received a quality improvement designation by the Spectrum Health and Ferris State University Institutional Review Boards. The P&T-approved renal dosing policy was instituted at Spectrum Health Butterworth and Blodgett Hospitals in Grand Rapids, Michigan on 1 March 2020. Two-month periods of January–February 2020 and April–May 2020 comprised the pre- and post-renal dosing policy implementation time periods, respectively. Prior to the policy implementation, decentralized pharmacists manually contacted prescribers for renal dosing recommendations using a P&T-approved standardized renal dosing protocol consisting of 34 medications. The renal dosing protocol further differentiated dosing recommendations by treatment indication when different doses of a specific drug were warranted based on diagnosis. In these instances, pharmacists determined the indication through electronic health record review or physician inquiry when necessary. The approved renal dosing policy permitted the same institution-approved renal dosing recommendations from this preexisting protocol to be independently executed by pharmacists without prescriber notification. The health record time from initial prescriber electronic order signature to pharmacist electronic order verification for new orders in the setting of renal impairment based on creatinine clearance assessment was collected and compared between pre- and post-policy time periods to evaluate the primary outcome of time to order verification. The secondary outcome compared the same pre-policy to the post-policy period for the incidence of an adverse event attributed to medication accumulation—specifically, the effect of fluconazole on corrected QT (QTc) interval lengthening by comparing baseline and on-fluconazole QTc assessments calculated via the Bazett[8] formula in the setting of renal impairment. Electrocardiogram (ECG) and corresponding QTc evaluation pre- and post-fluconazole initiation were voluntarily performed at a prescriber's discretion. Fluconazole dose adjustments were based on estimated creatine clearance (CrCl) with specific dosing regimens dependent on either the indication of esophageal/oropharyngeal candidiasis or candidemia.

A potential dosage adjustment due to renal impairment occurred when the estimated CrCl decreased to or below 50 mL/min. Non-dialysis renal dosing protocol ranges by CrCl included 50–30 mL/min, 29–10 mL/min, and less than 10 mL/min yet a recommended dose change within each respective CrCl range remained contingent upon the protocol-specific drug. Renal impairment was secondary to physician-diagnosed acute kidney injury (AKI), chronic kidney disease (CKD), end-stage renal disease, or acute-on-chronic kidney disease (AKI on CKD). Creatinine clearance was manually calculated using the Cockcroft-Gault equation for each patient using an Excel[9] spreadsheet and further adjusted for conditions associated with modified clearance as reported in published literature: paraplegia or quadriplegia spinal cord injury, actual body weight less than ideal body weight, body mass index (BMI) between 30 and 39.9 kg/m^2, and serum creatinine (SrCr) less than 0.8 mg/dL in individuals 65 years and older.[10,11] Based on these parameters, dose adjustments due to renal impairment on initial orders were classified as either "appropriate—no change required" (original order appropriate and did not need to be changed); "appropriate—order changed" (original order not appropriate but changed to an appropriate renally adjusted dosing regimen); "inappropriate—order not changed despite adjustment recommended per protocol" (original order not appropriate and not renally adjusted); and "inappropriate—order changed when not recommended by protocol" (original order changed to an inappropriate dosing regimen).

Table 1. Spectrum health pharmacy renal dosing protocol medications.

Medications included in the analysis	Medications not included in the analysis
Acyclovir	Cefazolin
Amoxicillin	Cefixime
Amoxicillin–clavulanate	Cefoxitin
Ampicillin	Ceftaroline
Ampicillin–sulbactam	Ceftazidime–avibactam
Aztreonam	Ceftolozane–tazobactam
Baclofen	Clarithromycin
Cefepime	Daptomycin
Ceftazidime	Flucytosine
Cefuroxime	Imipenem/cilastatin
Cephalexin	Peramivir
Ciprofloxacin	
Enoxaparin	
Ertapenem	
Famotidine	
Fluconazole	
Levofloxacin	
Meropenem	
Oseltamivir	
Penicillin G	
Piperacillin–tazobactam	
Tramadol	
Valacyclovir	

In addition, pharmacist-documented electronic interventions, each referred to as an "iVent" in the EPIC® electronic medical record, were also evaluated to observe the frequency of documented pharmacist evaluation of prescriber-initiated medication orders ordered in the setting of renal impairment.[12]

Inclusion criteria comprised inpatients at Spectrum Health Butterworth and Blodgett Hospitals receiving one of the 34 renal dosing protocol medications (Table 1) during the focused timeframe along with an estimated CrCl that did not exceed 50 mL/min nearest to and preceding initiation of a renal dosing protocol medication. The secondary endpoint assessed a documented QTc assessment before initiation as well as during fluconazole that required a dosing change relative to the assessed CrCl. Exclusion criteria included vulnerable populations (minors, pregnant, breastfeeding, and/or incarcerated); fewer than two inpatient doses of a protocol medication; and patients requiring continuous renal replacement therapy at any time during receipt of the renal dosing protocol medication. The evaluation was completed only on the first renally dosed medication administered during the patient's hospital admission.

Statistical analysis

A sample size of convenience was used without a power analysis conducted. Patient identification, chart review, collation of deidentified data, and reporting of results were completed within 12 months of institutional review board (IRB) approval. Study data were collected via EPIC® electronic medical record and managed using Research Electronic Data Capture® (REDCap, version 13.7.23) electronic data capture tools hosted at Spectrum Health.[13] Normally distributed numeric data were expressed as mean ± standard deviation and analyzed using two-sample independent *t*-tests. Non-normally distributed numeric data were expressed as median (25th and 75th percentiles) and analyzed using the Wilcoxon Rank Sum test.[14] Categorical data were expressed as frequency (percent) and analyzed using chi-square or Fisher's Exact test if more than 20% of the expected cell counts were less than 5; in these cases, an asterisk (*) was denoted next to the *p*-value (Tables 2 and 3). A *p*-value less than 0.05 was considered statistically significant.

Results

A total of 665 patient charts were reviewed and of those, 163 individuals were excluded. The reasons for exclusion consisted of 88 single-dose orders and 75 orders with a CrCl > 50 mL/min at protocol medication initiation. Of the 34 renal dosing protocol medications, 11 medications were not administered (not prescribed or did not meet study inclusion criteria) to the remaining 502 eligible patients during the study periods, thereby leaving 23 medications available to assess for the primary outcome (Table 1). There were no differences by age, gender, or creatinine clearance between the pre- and post-intervention groups.

Table 2. Renal dosing policy patient characteristics.

Baseline demographics	Full cohort ($N = 502$)	Pre-policy ($n = 278$)	Post-policy ($n = 224$)	p-Value
Age (years)†	73.8 ± 14.2	74.2 ± 14.0	73.4 ± 14.5	0.5452
Male (%)	230 (45.8)	124 (44.6)	106 (47.3)	0.5436
Hospital LOS (days)α	6 (3, 10)	5 (3, 10)	6 (3, 11)	0.1840
ABW (kg)α	79.0 (67.4, 95.1)	80.0 (68.2, 96.0)	78.2 (64.5, 94.7)	0.2449
BMI (kg/m^2)α	28.4 (23.9, 33.4)	28.7 (24.3, 34.0)	28.2 (23.4, 32.4)	0.2009
Baseline SrCr (mg/dL)α	1.15 (0.90, 1.75)	1.20 (0.90, 1.90)	1.63 (1.15, 2.48)	0.0660
Baseline CrCl (mL/min)α	43.4 (31.0, 53.9)	41.2 (29.4, 52.6)	46.0 (33.3, 55.9)	0.0521
SrCr nearest to and preceding renal dosing order (mg/dL)α	1.62 (1.13, 2.63)	1.63 (1.15, 2.48)	1.62 (1.10, 2.75)	0.6725
CrCl nearest to and preceding renal dosing order (mL/min)α	33.3 (23.1, 42.2)	34.1 (24.3, 42.7)	32.1 (21.9, 41.5)	0.2950

ABW: actual body weight; BMI: body mass index; CrCl: creatinine clearance; LOS: length of stay; NA: not applicable; SrCr: serum creatinine.
†Denotes mean with standard deviation.
αDenotes median with 25th and 75th percentiles.

For the primary outcome, the pre- and post-policy time from order signature to order verification was 9 (4, 26) min and 8 (3, 17) min ($p = 0.0861$), respectively. There were statistically significant interactions between renal impairment type ($p = 0.0012$) as well as dose adjustments on initial orders ($p = 0.0224$) between pre- and post-policy groups. This latter interaction was likely driven by a higher proportion of "appropriate—no change required" orders in the pre-policy group (74.1% vs 64.7%) and a higher proportion of "appropriate—order changed" orders in the post-policy group (14.8% vs 24.6%). The proportion of iVents opened was 15.5% in the pre-and 33.9% post-policy cohorts ($p < 0.0001$), respectively. A higher proportion of pharmacist-opened iVents for patients with a BMI between 30 and 39.9 kg/m^2 occurred in the post-policy group (14.0% vs 29.7%; $p = 0.0186$). There was no statistically significant evidence to suggest an association between renal impairment type and opened iVent when accounting for the time of policy implementation ($p = 0.8240$). Similarly, there was no statistically significant association between iVent and pre-/post-policy groups for BMI $\geq 40\,kg/m^2$ ($p = 0.2908$). Full results are provided in Table 2.

In all, 56 patients met the inclusion criteria for QTc interval lengthening for the fluconazole secondary outcome comparison. There were no statistically significant differences between pre- and post-protocol fluconazole recipients with regard to age, sex, weight, hospital length of stay, baseline SrCr, SrCr nearest to renal dosing order, initial or maintenance dose, duration, QTc-prolonging drugs (defined by presence and number) before or during fluconazole, renal dysfunction type, frequency of opening an iVent, dose adjustment type for the initial order, or QTc assessment frequency during therapy. Conversely, the median time from electronic order signature to verification decreased from 22 to 6 min ($p = 0.0252$) and pre-fluconazole baseline QTc assessment frequency increased from 50% to 92% ($p = 0.0010$) following policy implementation.

Fluconazole did not require a dose adjustment on the initial order in the setting of renal impairment among 25 of 32 (78%) pre-policy and 19 of 24 (79%) post-policy patients. Among patients indicated for a dose change per the renal dosing protocol, the fluconazole order was appropriately dose adjusted in 2 of 7 (29%) pre- and 4 of 5 (80%) post-policy patients. Therefore, the fluconazole order was not changed despite being indicated via protocol in 71% and 20% of pre- and post-policy patients, respectively. No orders were inappropriately changed when not recommended by protocol in either group. Both baseline and during fluconazole QTc data were only available for about 21% of each group, and the QTc interval during fluconazole increased relative to baseline in 3 of 7 (43%) pre-policy and 4 of 5 (80%) post-policy. No patients in the pre-policy and two patients in the post-policy groups had QTc intervals exceeding 500 ms.

Discussion

The primary endpoint of the overall time to order verification for medications that warranted renal dose adjustment based on an inpatient pharmacist-driven renal dosing policy was not statistically significant. Conversely for the same outcome, there was a statistically and debatably clinically significant median difference specifically for fluconazole. This distinction may highlight the variable renal dosing familiarity and complexity (i.e., patient weight and other diagnoses influencing renal clearance) among prescribers for the 23 antimicrobial, antifungal, and antiviral protocol medications observed. This rationale may be further supported by the higher proportion of pre-policy fluconazole compared to all pre-policy protocol medications whose initial orders were inappropriate yet not adjusted despite being indicated.

In addition, the secondary fluconazole result may reflect a Type I statistical error given the truncated 56-patient cohort partly attributed to prescriber discretion to obtain an ECG

Table 3. Renal dosing policy outcomes.

Characteristic	Full cohort (*N* = 502)	Pre-policy (*n* = 278)	Post-policy (*n* = 224)	*p*-Value
Time from order signature to order verification (minutes)[α]	8 (3, 22)	9 (4, 26)	8 (3, 17)	0.0861
Renal impairment type at time of renal dosing order (*n*, %)				
AKI	106 (21.1)	44 (15.8)	62 (27.7)	0.0012
AKI on CKD	105 (20.9)	59 (21.2)	46 (20.5)	
CKD	221 (44.0)	141 (50.7)	80 (35.7)	
ESRD	70 (13.9)	34 (12.2)	36 (16.1)	
Medication name the at time of renal dosing order				
Acyclovir	14 (2.8)	11 (4.0)	3 (1.3)	NA
Amoxicillin	7 (1.4)	6 (2.2)	1 (0.4)	
Amoxicillin–clavulanate	6 (1.2)	6 (2.2)	0 (0.0)	
Ampicillin	4 (0.8)	1 (0.4)	3 (1.3)	
Ampicillin–sulbactam	23 (4.6)	12 (4.3)	11 (4.9)	
Aztreonam	2 (0.4)	0 (0.0)	2 (0.9)	
Baclofen	11 (2.2)	7 (2.5)	4 (1.8)	
Cefepime	32 (6.4)	16 (5.8)	16 (7.1)	
Ceftazidime	2 (0.4)	2 (0.7)	0 (0.0)	
Cefuroxime	6 (1.2)	4 (1.4)	2 (0.9)	
Cephalexin	8 (1.6)	4 (1.4)	4 (1.8)	
Ciprofloxacin	8 (1.6)	5 (1.8)	3 (1.3)	
Enoxaparin	88 (17.5)	34 (12.2)	54 (24.1)	
Ertapenem	1 (0.2)	1 (0.4)	0 (0.0)	
Famotidine	45 (9.0)	23 (8.3)	22 (9.8)	
Fluconazole	56 (11.2)	32 (11.5)	24 (10.7)	
Levofloxacin	3 (0.6)	3 (1.1)	0 (0.0)	
Meropenem	3 (0.6)	2 (0.7)	1 (0.4)	
Oseltamivir	14 (2.8)	14 (5.0)	0 (0.0)	
Penicillin G	1 (0.2)	0 (0.0)	1 (0.4)	
Piperacillin–tazobactam	108 (21.5)	52 (18.7)	56 (25.0)	
Tramadol	58 (11.6)	43 (15.5)	15 (6.7)	
Valacyclovir	2 (0.4)	0 (0.0)	2 (0.9)	
Dose adjustment on the initial order				
Appropriate—no change required	351 (69.9)	206 (74.1)	145 (64.7)	0.0224*
Appropriate—order changed	96 (19.1)	41 (14.8)	55 (24.6)	
Inappropriate—order not changed when adjustment recommended per protocol	54 (10.8)	30 (10.8)	24 (10.7)	
Inappropriate—order changed when not recommended by protocol	1 (0.2)	1 (0.4)	0 (0.0)	

AKI: acute kidney injury; CKD: chronic kidney disease; CrCl: creatinine clearance; ESRD: end-stage renal disease; NA: not applicable; SrCr: serum creatinine.
[α]Denotes median with 25th and 75th percentiles.
*Fisher's Exact test was used if more than 20% of the expected cell counts were less than 5.

since only 38 (67.9%) patients received a pre-fluconazole baseline and 14 (25%) patients received a during fluconazole ECG evaluation. Prescriber discretion regarding whether to obtain an ECG assessment prior to and/or during fluconazole treatment could introduce selection bias based on individual patient concurrent risk factors for QTc prolongation despite the absence of any health system-driven electronic health record formal screening tool or alert to further predict QTc prolongation and/or Torsades de Pointes at time of inpatient order prescribing.[15,16] It further remains possible that the time to directly document an iVent itself, when documented, could add additional time to the overall order verification process as opposed to directly adjusting an order. The pharmacist iVent documentation time was not measured and this information could prove beneficial. Lastly, the study evaluated a change in renal function as a binary variable with or without the need for a dose change at the time of evaluation. As a result, the study did not appreciate the continuous severity of changing renal function that could lead to more systemic accumulation and risk for QTc prolongation in the setting of fluconazole. Despite the potential variation in systemic fluconazole exposure relative to initial indication (i.e., candidemia vs esophageal/oropharyngeal candidiasis) and corresponding protocol-recommended dose, the potential for QTc prolongation may have been minimized given that the renal dosing protocol recommended the same respective

modified dosing regimen for any CrCl below 50 mL/min as long as the patient did not require hemodialysis.

Although the time to order verification did not significantly decrease, this does not suggest that a pharmacist-driven renal dosing policy is not beneficial to inpatient pharmacy services. Pharmacists spend between 79% and 82% of their time on clinical activities.[17,18] Despite semantics variation between studies, pharmacist chart review consumes 10%–28% and prescriber communication an additional 1%–4% of all devoted clinical activity time.[17,18] While this study focused solely on renal dosing, these interventions existed concurrently with multiple efforts including, but not limited to, intravenous to oral route conversion, medication history collection, therapeutic drug monitoring, discharge counseling, additional prescriber recommendations, clinical rounds, and other electronic medication order verification. Given the potential order verification time enhancement at the individual drug level as well as the overall increased dosing appropriateness among initial orders post-implementation, renal dosing policies improve patient care quality and pharmacist clinical activity efficiency by permitting additional time to devote to other patient care responsibilities.

In addition, pharmacist-driven renal dosing policies reduce drug expenditures.[19] The University of Colorado Hospital, a 673-bed academic medical center, demonstrated a $3,919.87 drug product savings during a 2-month study period from seven renally dose-adjusted medications. This extrapolated to an annual cost savings of approximately $23,519. The cost reduction stemmed from 422 dose adjustments with 319 (74%) of pharmacist changes producing a dose decrease and nearly one-fourth (24%) of changes yielding a dose increase. The overall cost savings were primarily attributed to fewer dispensed medications due to reduced dosing frequencies.[19] While the present study did not specifically perform a cost-savings analysis due to the limited observation period following policy approval, it remains reasonable to anticipate a parallel reduction in pharmacy drug expenditure.

The current study's strengths included a relatively large sample size for the primary outcome in addition to inclusion and exclusion criteria clearly defined to minimize ambiguity. Despite being a two-hospital study, this policy could be incorporated at other institutions without requiring additional personnel to implement. One study limitation included a sample size of convenience without a predetermined power analysis. In addition, the small sample size for the secondary outcome related to one adverse drug effect associated with fluconazole. Pregnancy, a condition associated with altered renal clearance, was excluded given its vulnerable population designation. There was inconsistent data exportation from EPIC®[12] into REDCap®[13] for order signature time to order verification, which resulted in reviewing each patient chart to perform manual adjustments to ensure the accuracy of these respective times. Values for creatinine clearance were manually calculated for each patient chart and this could introduce human error even though these calculations were computed twice along with the use of a Microsoft Excel[9] spreadsheet equation to ensure accuracy. Given the relatively close proximity between the policy implementation and post-policy assessment period, the early follow-up period may have prevented a more accurate evaluation of pharmacist verification time proficiency as the median documentation time could have further improved (i.e., decreased) with an extended follow-up period. Furthermore, there was no way to determine if any of the results were affected by the changes in patient census or pharmacist daily workload at the beginning of the COVID-19 pandemic. Aside from these considerations, this is the only known study to measure time from order signature to order verification for a pharmacist-driven renal dosing policy since the majority of research regarding pharmacist-driven renal dosing policies has focused on cost-saving initiatives and/or the prevention of adverse drug events.[1–4,17–19]

The statistically significant results demonstrated a higher proportion of "appropriate—no change required" orders in the pre-policy group (74% vs 65%) and a higher proportion of "appropriate—order changed" in the post-protocol group (15% vs 25%). These findings may reflect three possible explanations. First, it is possible that while collecting data from the pre-policy group, potential interventions for renal dose adjustment were overlooked and also missed by pharmacists. Another theory may involve prescribers being less vigilant about renal dose adjustments post-policy implementation. If prescribers knew that pharmacists reviewed every order for renal dose adjustments with the capability to adjust the orders independently, they may have been less likely to renally dose the medication before signing the order. One study surveyed medical residents regarding prescribing behaviors for patients with renal impairment.[20] Only 5% of the medical residents reported checking whether their order needed adjustment without first observing for an abnormal SrCr. The study authors inferred that a majority of residents were not calculating creatinine clearance for every patient although their prescribing behaviors were related to fictitious patients on a survey and therefore may not extrapolate to clinical practice.[20] Alternatively, prescribers in the post-policy cohort may have had additional experience in renal dosing, thereby indirectly facilitating order verification time by the pharmacist. The study did not control for this potential bias as the intent was to evaluate implementation in a common hospital practice setting. The third theory posits that prescribers were more willing to maintain the initial dosing strategy knowing that some of these medications had an increased volume of distribution and plasma clearance; therefore, continuing the same dose would partially offset the reduced renal function in patients with a BMI over 30 kg/m^2.[10]

The secondary endpoint results may have been influenced by other QTc prolonging medications co-administered at the time of the fluconazole order despite the presence, without a

focus on a specific agent or dose, of other QTc-prolonging drugs during fluconazole not being statistically different between groups ($p = 0.6798$). Reflective of the challenges encountered in clinical practice, there was no way to elucidate if an individual's QTc prolongation was caused by fluconazole and/or the high percentage of concomitant QTc-prolonging medications. Time from order signature to order verification between the fluconazole protocol timeframes significantly decreased from a median of 22 min pre-policy to 6 min post-policy ($p = 0.0252$). This may suggest that specific medications may take the prescriber more time to evaluate prior to responding to the pharmacist with the correct dose and further highlight the need for assessment on time to order verification after implementation of a pharmacist-driven renal dosing policy.

Conclusion

The implementation of an inpatient pharmacist-driven renal dosing policy at Spectrum Health Blodgett and Butterworth Hospitals did not show a significant decrease in time from order signature to order verification among all medications that warranted renal dose adjustment. A smaller individual drug cohort demonstrated a verification time reduction exclusive to fluconazole orders yet this did not confer a decrease in QTc prolongation associated with fluconazole following the pharmacist-driven renal dosing policy implementation. Further research to evaluate time spent by pharmacists to document an iVent or time spent by prescribers to reorder a medication may be beneficial to assess the efficiency of a pharmacist-driven renal dosing service. Additional research may also prove beneficial to evaluate a longer time interval to obtain a larger sample size to evaluate fluconazole as well as other renally dosed medications and their corresponding adverse effects plausibly attributed to drug accumulation. Inpatient pharmacy departments that do not currently utilize a pharmacist-driven P&T-approved renal dosing protocol should evaluate the utility of implementation when considering the concurrent patient care responsibilities of their hospital pharmacists.

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Declaration of conflicting interests

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Ethics approval

Ethical approval for this study was waived by The Spectrum Health Institutional Review Board and The Ferris State University IRB because it was deemed a quality improvement study. The waiver number for Spectrum Health IRB is #2020-411 and for Ferris State University IRB is IRB-FY20-21-25.

Informed consent

The requirement of written informed consent from the subjects prior to study initiation was waived by the Institutional Review Board/Ethics Committee.

Trial registration

Not applicable.

ORCID iD

Dane Shiltz https://orcid.org/0000-0003-1876-8766

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