Impact of a Computerized Alert During Physician Order Entry on Medication Dosing in Patients with Renal Impairment

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Computerized assistance to clinicians during physician order entry can provide protection against medical errors. However, computer systems that provide too much assistance may adversely affect training of medical students and residents. Trainees may rely on the computer to automatically perform complex calculations and create appropriate orders and are thereby deprived of an important educational exercise. An alternative strategy is to provide a critique at the completion of an order, requiring the trainee to enter the entire order but displaying an alert if an error is made. While this approach preserves the educational components of order-writing, the potential for errors exists if the computerized critique does not induce clinicians to correct the order. The goal of this study was to determine (a) the frequency with which errors are made by trainees in an environment in which renal dosing adjustment calculation for antimicrobials are done by the system after the user has entered an order, and (b) the frequency with which prompts to clinicians regarding these errors leads to correction of those orders.

BACKGROUND

Computerized Physician Order Entry (CPOE) has been shown to decrease medication errors[1], especially when decision support features are included as part of the CPOE system[2,3]. One specific type of error for which computerized decision support (CDS) has been shown to be effective is the adjustment in dosing of drugs given to patients with renal impairment. Recently, Chertow *et al.* demonstrated that limitation of the dose and interval choices displayed to clinicians improved the frequency of appropriate orders for patients with renal dysfunction[4]. This intervention replaces three tasks normally performed by the clinician: (a) recollection of patient's impaired renal function, (b) lookup or calculation of degree of renal insufficiency (i.e. creatinine clearance), and (c) determination of appropriate change in dose based on the degree of renal insufficiency. Computers can perform all of these tasks consistently and appropriately, providing maximal protection to the patient. However, the automatic performance and presentation of results may deprive medical students and residents of the educational benefits of repeatedly performing these tasks and incorporating them into their order writing process, a skill which may be necessary if/when the trainee begins practicing in an environment in which CPOE/CDS is not available.

An alternative strategy is to allow the clinician to enter the order without any assistance from the computer, but provide instant feedback if the order is deemed incorrect. This potentially achieves two objectives. First, the user is made to feel that he/she is expected to enter the dose correctly and not rely on the system's CDS. Additionally, informal conversations with our users suggests that receiving an alert is subtly remonstrative in that it highlights a potential error made by the clinician. This provides reinforcement, albeit negative, for the trainee to be more careful. While these effects are desirable from a training standpoint, this alerting strategy incurs the risk of the user ignoring the warning generated by the system, as passive reminders may be less effective at influencing behavior[5].

The goal of our study was to evaluate this method of providing dosing assistance to physicians ordering pharmaceuticals for patients with renal impairment. We sought to determine if the presence of this alert would lead to a high error rate (in the "first try" orders entered by the clinician) or to increasing error rates as a training year progresses (as users begin to rely on the system "safety net"). Additionally, we attempted to determine the frequency with which alerts presented at the completion of an order actually lead to alteration of the incorrect order.

METHODS

This study was performed at the New York Weill Cornell Medical Center of The NewYork

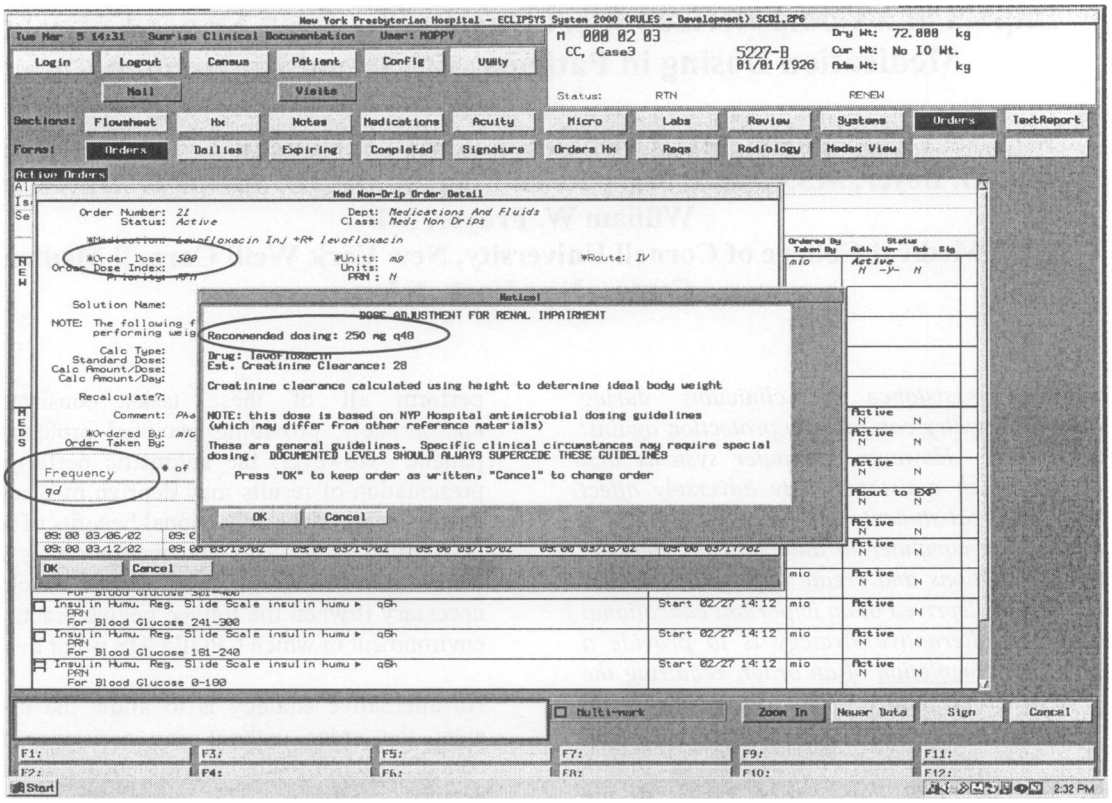

Figure 1: Renal dosing alert : After the user has already selected the standard dose of 500 mg qD, the clinical alert popup informs the user of the appropriate recommended dose.

Presbyterian Hospital, a tertiary care academic medical center located in New York City, N.Y. At the time of the study, CPOE was "live" on 2 general medical units, 4 medical subspecialty units (hematology / oncology, cardiac telemetry, pulmonary stepdown, renal), the medical and cardiac intensive care units (MICU and CCU, respectively), and the neurology/neurologic surgery (Neuro/NS) unit.

We developed an alert within our CPOE system[6] designed to evaluate orders entered for patients with renal dysfunction. As the clinician completes an order, the dose and dosing interval are checked against our hospital formulary's dosing guidelines for the drug ordered and the patient's calculated[7] or measured creatinine clearance (C_{CR}). If the order is not dosed according to hospital guidelines, an alert is generated and a modal dialog box is displayed to the user (figure 1). This text of the popup box includes the recommended dosing and some of the data used to determine the dosing. The user then has the option to complete and sign the order as entered or to change the order prior to signing it. Currently, our pharmacy has dosing guidelines for the 21 antimicrobials on formulary, and the alert was evaluated for this subset of drugs.

For this study, orders and any associated alerts from a 3 month period (June 2001 – August 2001) were reviewed within our electronic medical record database. An application was developed to review and classify all drug orders. If a measured C_{CR} was unavailable, creatinine clearance was calculated for each order using age, height (if available), weight (if height unavailable), and last serum creatinine prior to the order using the standard Cockcroft-Gault equation[7]. This program then identified all antimicrobial orders requiring dose adjustment based on C_{CR}. The number of identified orders reflects the total number of (antimicrobial) orders requiring some dose modification because of renal insufficiency independent of whether the order was initially entered correctly or incorrectly by the ordering clinician. To determine the number of dosing errors (i.e. the number of orders, which were initially entered at doses or frequencies inappropriately high for the degree of renal impairment), renal dosing

Unit	Orders in pt. with renal impairment	Alerts	%	p
Neuro/NS	43	15	34	
Gen Med	216	68	31	NS
MICU/CCU	569	129	23	<0.01
Renal	209	30	14	0.01

Table 1: Renal dosing error rates by unit

Training Level	Orders in pt. with renal impairment	Alerts	%	p
Inexperienced	1011	240	24	NS
Experienced	326	64	20	

Table 2: Error rate by level of experience

alerts were identified within the database. Since an alert was only generated if the clinician's initial order was not appropriate, the number of alerts reflects the number of dosing errors made by clinicians during order entry. However, because our formulary antimicrobial dosing guidelines do not always match those of a standard pocket reference used by the majority of our housestaff[8], a physician-reviewer manually classified each alert as either false positive (order initially dose adjusted according to recommendations other than our hospital guidelines) or true positive (order not correctly adjusted according to any guideline). For purposes of this study, only true positive alerts were considered to be dosing errors*. The dosing error rate was defined as the number of true positive alerts divided by the number of antimicrobial orders identified for patients with renal dysfunction (as described above). Finally, to evaluate the clinician's response to the alert, the reviewer classified the final signed order as either having been corrected as recommended by the alert or not corrected. The number of alerts leading to adjustment divided by the number of true positive alerts was the frequency with which alert prompts led to adjustment of incorrect orders.

Categorical outcomes were compared by a χ^2 statistic using EpiInfo 6 (Centers for Disease Control).

RESULTS

During the three month study period, 4596 orders were written for antimicrobials. Of the 4596 orders, 3636 of them had a calculable C_{CR} at the time of the order (patients whose admission orders were written prior to charting of height/weight would not have evaluable C_{CR}). Of those, 1337 (37%) orders were in patients with renal dysfunction of sufficient magnitude to require dose adjustment. True positive alerts were generate in response to 304 (23%) of the orders. This number reflects the overall error rate. An additional 195 (15%) orders generated false positive alerts (order written according to published guidelines which differ from our pharmacy dosing policy).

Significant differences in rates of dosing errors were observed between different types of inpatient units (Table 1). While no differences were observed between neurology and general medicine, higher error rates were observed on general medical units than in intensive care units (31% vs. 23%, p<0.01), and in intensive care units compared with the renal unit (23% vs. 14%, p=0.01). To identify changes in error rates as a result of increasing reliance on the computerized alert, we compared error rates in July and August (at which point interns, who enter the overwhelming majority of orders, are inexperienced with our CPOE system and the CDS features) with those in June (by which time our trainees are very experienced with the system). No difference in error rate was observed when orders written by "experienced" housestaff (June) were compared with those written by "inexperienced" housestaff (July, August) (24% vs. 20%, p=NS) (Table 2).

Of the 304 orders generating true positive alerts, 159 (52%) orders were adjusted in response to the alerts. No differences were observed in the rates of orders adjusted in response to the alerts on different units

Unit	Alerts	Orders changed	%	p
Neuro/NS	15	5	33	NS
Gen Med	68	41	60	
MICU/CCU	129	68	53	
Renal	30	13	43	

Table 3: Adjustment in response to alert by unit

Training Level	Alerts	Orders Changed	%	p
Inexperienced	240	113	47	<0.01
Experienced	64	46	72	

Table 4: Adjustment in response to alert by level of experience

* Note that "dosing errors" does not imply incorrect dosing administered to the patient, but rather refers to errors in the order entered which subsequently generated an alert to the ordering clinician.

(Table 3) (although the numbers of orders per unit type were small and the possibility of β error exists). However, "experienced" housestaff (June) corrected their errors in response to alerts for a significantly greater percentage of orders than "inexperienced" (July/August) housestaff (72% vs. 47%, $p<0.01$) (Table 4).

DISCUSSION

This study sought to determine the frequency of renal dosing errors in a CDS environment where renal dosing adjustments are not proactive but are suggested in an alert that is displayed upon completion of an order that is deemed by the system to be incorrect. We observed an error rate of approximately 23%. While an exact background rate of renal dosing errors is not known, this number matches the rate of "frequency errors" in a previously published study of CPOE and medication errors[3], and is below the rate of inappropriate orders in the control period of a study of renal dosing assistance at a similar institution.[4]. Additionally, our error rates inversely correlate with the expected degree of vigilance regarding renal dysfunction (renal service vs. ICU vs. general medicine). This low level of errors and variation by type of unit suggest that our users have *not* developed a significant dependence on the dosing assistance provided by the system, but instead continue to perform their own calculations and dose adjustments. Additionally, the lack of change in error rate between July/August, the start of the training year, and June, the end of a training year, speaks against development of dependence on the system decision support features.

We observed that approximately 52% of true positive alerts lead to a change in the order. Interestingly, though, our data suggest that experienced housestaff are more likely to follow the computerized recommendations than inexperienced housestaff, with experienced housestaff adjusting their order for 71% of orders generating an alert. It should be noted that adjustments were scored based only on the order signed immediately after the alert. Anecdotally, we have noted that a significant number of orders are discontinued and re-ordered according to the alert guidelines shortly after the time of the order which triggered the alert. We hypothesize that experienced housestaff are comfortable making the decision to adjust the dose, while inexperienced housestaff do not immediately follow the computerized recommendations, but rather refer to either reference materials or more experienced clinicians and make adjustments later. Thus, the percentage of alerts leading to a change in the order is potentially higher than the 52% observed. A more detailed review of these orders is required to confirm or disprove this hypothesis.

One limitation of this study is that the clinicians' responses to the alerts were determined and classified by a single reviewer. A more extensive review by multiple observers is needed to confirm these classifications.

Another important observation in this study is the high volume of false positive alerts due to dosing adjustments being made according to clinically acceptable reference materials which differ from our pharmacy guidelines. While this occurs in only 15% of all orders, this number accounts for approximately one third of all renal dosing alerts displayed. This can lead to confusion and may decrease the impact of true positive alerts.

CONCLUSION

We have developed and implemented an alerting strategy, which provides renal dose adjustment assistance in a manner, which does not adversely affect the educational benefits of traditional manual dose determination. We have found that by allowing the clinician to take a "first crack", the error rate by our housestaff has remained low. When ordering errors are made, the alert leads to an immediate adjustment in dose a significant percentage of the time, suggesting that our clinicians are reading and considering the recommendations appropriately. Further work is needed to determine if the actual adjustment rate is higher than captured by looking at the immediate response to the alert. Additionally, a strategy for minimizing false positive alerts (generated when orders are written according to acceptable guidelines but not according to our local guidelines) needs to be devised and implemented.

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