Failure to utilize functions of an electronic prescribing system and the subsequent generation of ‘technically preventable’ computerized alerts

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ABSTRACT
Objectives To determine the frequency with which computerized alerts occur and the proportion triggered as a result of prescribers not utilizing e-prescribing system functions.
Methods An audit of electronic inpatient medication charts at a teaching hospital in Sydney, Australia, was conducted to identify alerts fired, to categorize the system functions used by prescribers, and to assess if use of short-cut system functions could have prevented the alerts.
Results Of the 2209 active orders reviewed, 600 (27.2%) triggered at least one alert. Therapeutic duplication alerts were the most frequent (n=572). One third of these (20.2% of all alerts) was ‘technically preventable’ and would not have fired if prescribers had used a short-cut system function to prescribe. Under-utilized system functions included the option to ‘MODIFY’ existing orders and use of the ‘AND’ function for concurrent orders. Pregnancy alerts, set for women aged between 12 and 55 years, were triggered for 43% of drugs ordered for this group.
Conclusion Developers of decision support systems should test the extent to which technically preventable alerts may arise when prescribers fail to use system functions as designed. Designs which aim to improve the efficiency of the prescribing process but which do not align with the cognitive processes of users may fail to achieve this desired outcome and produce unexpected consequences such as triggering unnecessary alerts and user frustration. Ongoing user training to support effective use of e-prescribing system functions and modifications to the mechanisms underlying alert generation are needed to ensure that prescribers are presented with fewer but more meaningful alerts.

BACKGROUND AND OBJECTIVES
Electronic prescribing (e-prescribing) systems with decision support are increasingly being adopted by hospitals around the world as a means of reducing prescribing errors. These systems eliminate illegible handwriting, increase order accuracy and completeness, and improve response time and continuity of care. Computerized alerts integrated into e-prescribing systems have the potential to reduce prescribing errors because they warn prescribers about possible risks such as allergies, inappropriate doses, and duplicated orders. In a recent systematic review, most studies evaluating the effect of computerized alerts on prescribing behavior found positive and often substantial effects. For example, presentation of alerts designed to reduce the use of contraindicated drugs in patients with renal failure resulted in a large drop in the likelihood of a patient receiving at least one dose of contraindicated medication. Embedding real-time alerts in an e-prescribing system is a challenge in any hospital setting. To ensure that decision support remains relevant and effective, it has been suggested that ongoing monitoring of alerts that are triggered and the subsequent actions taken by prescribers is required. The majority of previous research evaluating alert effectiveness has adopted this approach. The evaluation methodology chosen at our site was initially qualitative. We observed prescribers use the e-prescribing system on ward rounds and discovered that approximately half of the medication orders initiated by doctors triggered computerized alerts. We found that prescribers rarely read the alerts and these alerts were therefore having little impact on prescribing behaviors on ward rounds.

Interestingly, during observations it was noted that a number of alerts were triggered because prescribers were not utilizing all the system functions. For example, instead of using the ‘THEN,’ ‘AND,’ or ‘OR’ functions which allow similar sequential, concurrent, or alternative orders for the same medication to be prescribed together (eg, frusemide 40 mg in the morning ‘AND’ 20 mg at midday), users often prescribed the two orders separately, which resulted in the triggering of a therapeutic duplication alert.

Sub-optimal use of technological systems has been identified as a potential cause of failure of systems following their implementation. It is well known that most users of applications utilize only a subset of system features or functions and several longitudinal studies have shown that despite considerable experience using a technological system, many users never progress beyond a minimally sufficient skill level. For example, the majority of Microsoft Excel users utilize only the low-level features of spreadsheets. Sub-optimal use of health information technology has received limited attention in the literature, however studies on workarounds show that clinicians may use applications in less optimal ways to manage problematic or poorly designed information technology. For example, users of an electronic patient record used the free-text boxes in the application instead of the appropriate in-built functions because the functions were difficult to locate.
another study, pre-written order-sets in a computerized provider order entry system were not used by doctors because the order-sets were classified and so arranged in a way not familiar to prescribers. No studies have previously examined the association between the use of functions of an e-prescribing system and the generation of computerized alerts.

While e-prescribing systems are designed to enhance efficiency in prescribing by, for example, eliminating the need to re-enter information about a new medication order when it is similar to an older order, little research has examined how such design features require changes in ways of working and conceptualizing tasks. Nor has previous research focused on identifying the consequences of unchanging user work practices when change is envisioned by system designers. This study set out to examine how use of e-prescribing system functions by prescribers can influence alert generation. The study was designed to further our understanding of the mechanisms underlying alert generation, allow targeted removal of particular alert types, and indicate system functions where suboptimal use was frequent.

**METHODS**

**Study site**

The study was conducted at a teaching hospital with approximately 320 beds in Sydney, Australia. The hospital specializes in heart, lung, and bone marrow transplantation, cardiology, cancer, HIV medicine, respiratory medicine, drug and alcohol services, and general community health problems, but does not provide pediatric or maternity services.

**e-Prescribing system**

At the time of the study (June–July 2011), all inpatient wards used the e-prescribing system, MedChart (Version 4.2.0B1; http://www.isofthealth.com), except for the emergency department. Wards (typically 34 beds) varied in the number of computers available, but all were equipped with on average eight wireless laptops fixed to lightweight trolleys and eight desk-top computers located at clinical work stations. As MedChart could be accessed from any computer on the hospital network, doctors could prescribe on or off the ward.

MedChart is an electronic medication management system that allows prescribing, pharmacy review, and drug administration. The system is integrated with the hospital’s clinical information system, which includes online ordering and results reporting for laboratory and imaging tests, paging, rostering, and clinical documentation.

Electronic prescribing in MedChart can be completed in three ways: (1) long-hand prescribing, where the doctor enters all order parameters (eg, dose, administration time, etc) after he/she selects a medication name (see figure 1), (2) ‘quicklists,’ or pre-written orders, where the order parameters are pre-populated, and (3) ‘protocols,’ collections of pre-written orders, for example, the blood and marrow transplant hematology protocol included 26 medication orders. As can be seen in the bottom right-hand corner of the prescribing screen shown in figure 1, MedChart also includes short-cut functions (THEN, AND, and OR) that allow similar sequential, concurrent, or alternative orders for the same medication to be prescribed together. For example, if a doctor wished to prescribe frusemide in the morning and at midday, then they would enter an order for frusemide in the morning and then click the ‘AND’ button. This would bring up a new order screen below the initial frusemide order screen and the prescriber would then be required to make only one change to this additional order (change morning to midday). Use of this short-cut function would save the prescriber up to 11 mouse clicks. During a 2 h MedChart training session (compulsory for all doctors), prescribers are shown where to find the short-cut functions and are required to complete several case scenarios using the system short-cuts. Prescribers are encouraged to use the short-cut functions as they save the prescriber significant amounts of time.

![Figure 1](https://www.isofthealth.com)  
**Figure 1**  
Doctor’s prescribing screen displayed when the prescriber selects Metformin (500 mg) Modified Release Tablet from the product list.
Computerized alerts
At the time of the study, decision support alerts enabled in MedChart included allergy and intolerances checking, pregnancy warnings, therapeutic duplication warnings, some dose range checking, and approximately 100 hospital developed messages offering prescribers advice about the medication selected (see table 1). Drug–drug interaction alerts were not yet operational. The alerts appeared to the prescriber immediately following the selection of a drug or drug product as a new screen. Alerts varied in length, but all used Courier 10 font and included a bold heading specifying the alert type (eg, ‘Substance Duplication’). An example alert appears in figure 2.

Approximately half of the alerts were for information only (ie, prescribers were not required to take action, just to click past the alert screen), while others required the prescriber to take action. In most of these latter cases, the alerts required prescribers to first tick the ‘override box’ (but not to provide a reason) and then close the alert screen (see alert #2 in figure 2). In approximately 10% of the alerts, prescribers were required to also type a reason for overriding the alert in a free-text box before proceeding with the order. All but seven of the decision support alerts allowed the prescriber to continue to prescribe a medication following the warning presentation regardless of whether they changed their order in response to the alert.

Technically preventable alerts
No reporting function was available within MedChart to allow extraction of information about triggered alerts, thus it was necessary to conduct a detailed audit of electronic medication charts to identify alerts presented to prescribers. This approach allowed identification of the exact process used by prescribers to enter each medication order into the e-prescribing system and of the alerts generated as a result of the ordering process used. In this way, the association between the system functions used and alert firing could be established. For all orders in which at least one alert was triggered and overridden, an assessment was made as to whether the use of a different system function for the same order could have prevented the alert from firing. Alerts were determined to be technically preventable if they were triggered as a result of a prescriber failing to use the system shortcut functions (THEN, AND, and OR) or failing to use the MODIFY function that allowed medication orders to be edited, rather than ceased and re-ordered, when modifications to an order were required (eg, a change in dose).

Only alerts that were ‘overridden’ by prescribers were visible on the electronic medication charts at review. If a medication order was not proceeded with following the presentation of an alert, the order (and with it the accompanying alert information) was lost from the system.

Procedure
A pilot study comprising a review of 50 inpatient electronic medication charts was conducted to obtain an estimate of the proportion of alerts that were technically preventable (ie, triggered as a result of system functions not being utilized). We found approximately five alerts for every 10 orders and an average of 12 orders per patient. Approximately 15% of the alerts were determined to be technically preventable. Using these figures, we calculated that the sample size needed to estimate the proportion of technically preventable alerts with precision ±2.5% (95% confidence limit) was approximately 145 patient charts. Using this estimate, we reviewed 180 patient medication charts to reliably identify the proportion of alerts triggered as a result of prescribers not utilizing e-prescribing system functions.

For the main study, a clinical pharmacist reviewer randomly selected patients each day (using a random number generator) from a list of all inpatients received every morning from the hospital Medical Records Department. If a prescriber had received an alert while ordering a medication, a small icon appeared beside the medication name on the electronic chart. The reviewer could determine what alert(s) had fired by clicking on this icon. Electronic charts were reviewed daily (Monday–Friday) for 6 weeks until the required 180 patient charts had been audited for alerts.

Patient medical record number (MRN), age, sex, ward, and the admitting consultant were recorded for each selected patient record. The total number of active orders, number of active orders with at least one alert, and total number of alerts were recorded for each patient. All medication orders active at the time of review were examined in detail. For each order with at least one alert, the following information was collected: prescriber, medication name, date and time ordered (if available), dose

Table 1  Alert types enabled within the MedChart system

<table>
<thead>
<tr>
<th>Alert type</th>
<th>Description</th>
<th>Example of trigger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allergy and intolerances</td>
<td>Displays when a patient is prescribed a medication containing a generic component that is identical to or belongs to the same therapeutic class as a generic component to which the patient has a recorded allergy or intolerance</td>
<td>A fentanyl transdermal patch is ordered for a patient who has a recorded intolerance to codeine (both drugs are opioid analgesics)</td>
</tr>
<tr>
<td>Pregnancy</td>
<td>Displays when a medication belonging to an Australian Advisory Committee on Prescription Medicines (ACPM) category other than ‘A’ is prescribed for a female patient in the age range of 12–55 years Note: all ACPM categories except A indicate a possibility of harmful effects to a fetus (<a href="http://www.tga.gov.au/hp/medicines-pregnancy.htm">http://www.tga.gov.au/hp/medicines-pregnancy.htm</a>)</td>
<td>A gentamicin injection is ordered for a female patient aged 40  Gentamicin, an aminoglycoside antibiotic, is a category D drug (drug which has caused, is suspected to have caused, or may be expected to cause, an increased incidence of human fetal malformations or irreversible damage)</td>
</tr>
<tr>
<td>Therapeutic duplication</td>
<td>Displays when a patient is prescribed a medication containing a generic component that is identical to or belongs to the same therapeutic class as a generic component that has already been prescribed. Alert displays if both orders are active, or if the first order is no longer active but was ceased &lt;24 h previously</td>
<td>A morphine injection is ordered for a patient who has an existing order for oxycodone tablets (both drugs are opioid analgesics)</td>
</tr>
<tr>
<td>Dose range</td>
<td>Displays when planned and indicative doses for a medication being prescribed exceed the recommended maximum therapeutic dose</td>
<td>See box 1. The maximum recommended dose of paracetamol is 4000 mg (8 × 500 mg tablets) in 24 h. As some doses are given late, the dose range check is set at 5001 mg in 24 h</td>
</tr>
<tr>
<td>Local message</td>
<td>Displays when a patient is prescribed a medication linked to a local message</td>
<td>See box 2 for an example of a local message (oxycodone formulations and brands)</td>
</tr>
</tbody>
</table>
medication schedule (eg, regular, PRN (as required)) and alert type (eg, allergy, duplication; see table 2). For all duplication alerts, the following additional information was collected: name of duplicated drug, schedule of duplicated drug, reason for the duplication (eg, different drugs belonging to the same therapeutic drug class), whether the duplication alert was technically preventable, and an alternative system function that would have prevented the alert from triggering (eg, use of the ‘AND’ function). Prescriber level (eg, intern) and admitting specialty (eg, cardiology) were subsequently collected from the hospital’s clinical information system.

**Statistical analysis**

Descriptive statistics (percentages, means, medians, and IQR) were used to summarize the key characteristics of patients, orders, and alerts. Pearson’s $\chi^2$ test and two-sample t tests were applied to further test associations between variables of interest. All p values calculated were two-sided with a significance level set at 5%.

**RESULTS**

**Patients and orders**

In the random sample of 180 patients, the mean age was 63.7 years (range 20–100 years) and 104 (57.7%) were male. A total of 2209 medication orders were active for the 180 patients (mean 12.3 orders/patient, median 11, IQR 8–16). See table 2 for order types and alert frequencies for each order type.

PRN orders were more likely to have an alert than regular, variable dose or STAT (immediately) orders ($\chi^2$=31.88, p<0.0001). PRN orders with alerts were also found to have a greater number of alerts (1.74, 95% CI 1.60 to 1.89) than regular orders with alerts (1.46, 95% CI 1.37 to 1.55; p=0.001). Orders for oxycodone (n=68) triggered 143 of the total of 934 alerts (15.3%), followed by orders for morphine (n=32 orders, 58 alerts, 6.2%), paracetamol (n=42 orders, 55 alerts, 5.9%), and temazepam (n=26 orders, 39 alerts, 4.2%).

**Alert types**

Of the 2209 active orders reviewed, 600 (27.2% of all orders) had one or more computerized alerts (table 2). A total of 934 alerts were identified (mean 1.6 alerts/alerted order, median 1, IQR 1–2). Table 3 shows that the majority of alerts were duplication or local messages.

**Prescribers**

A total of 149 prescribers were responsible for initiating the 600 orders with alerts. Most (96.8%) medication orders with alerts were initiated by junior doctors (house staff), with only 19 medication orders with alerts found to be initiated by a specialist consultant. On average, orders generated by interns had fewer alerts (1.41 alerts/order, 95% CI 1.29 to 1.54) than registrars (3–6 years after graduation) (1.61, 95% CI 1.48 to 1.74; p=0.03) or residents (1.61, 95% CI 1.47 to 1.76; p=0.04).

**Technically preventable alerts**

One third of the duplication alerts (n=189, 20.2% of all alerts) were determined to be the result of prescribers not utilizing available e-prescribing system functions; that is, if the prescriber did not utilize available system functions, the alert would not have appeared.

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**Table 2** Order types and alert frequencies

<table>
<thead>
<tr>
<th>Order schedule</th>
<th>Number of orders (% of total orders)</th>
<th>Number of orders with alerts (% of corresponding order schedule)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular</td>
<td>1587 (71.8)</td>
<td>379 (23.9)</td>
</tr>
<tr>
<td>PRN</td>
<td>586 (26.5)</td>
<td>211 (36.0)</td>
</tr>
<tr>
<td>Variable dose</td>
<td>24 (1.1)</td>
<td>7 (29.2)</td>
</tr>
<tr>
<td>STAT</td>
<td>12 (0.5)</td>
<td>3 (25.0)</td>
</tr>
<tr>
<td>Total</td>
<td>2209 (100.0)</td>
<td>600 (27.2)</td>
</tr>
</tbody>
</table>

PRN means when necessary; STAT means immediately.

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**Table 3** Frequency of alert types

<table>
<thead>
<tr>
<th>Alert type</th>
<th>Number (% of total alerts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duplication</td>
<td>572 (61.2)</td>
</tr>
<tr>
<td>Local messages</td>
<td>232 (24.8)</td>
</tr>
<tr>
<td>Pregnancy</td>
<td>100 (10.7)</td>
</tr>
<tr>
<td>Allergy</td>
<td>21 (2.3)</td>
</tr>
<tr>
<td>Dose range</td>
<td>9 (1.0)</td>
</tr>
<tr>
<td>Total</td>
<td>934 (100)</td>
</tr>
</tbody>
</table>

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**Figure 2** Computerized alert. Two alerts (a local message and ‘Substance Duplication’) were triggered in response to Ceftriaxone being selected.
had used a short-cut function to order the medication in MedChart, the duplication alert would not have triggered. Most frequently, a prescriber ceased an existing order and re-ordered the medication with one parameter different (eg, dose) instead of using the MODIFY function to change the existing order. Table 4 shows alternative ways to prescribe and the proportion of duplication alerts which could have been prevented by using these system functions. Table 5 includes some examples of duplication alerts that were determined to be either technically preventable or not preventable with use of an alternative prescribing method in MedChart.

A large proportion (n=240) of alerts where the order was re-ordered and ‘duplicate’ order were both active were determined to be non-preventable; however, in the case of duplications where one of the orders was ceased, over half the duplication alerts (n=153) could have been prevented with use of a system function. The majority of these preventable therapeutic duplication alerts (n=110) would not have been triggered if prescribers had used the MODIFY function in order to alter an existing order.

**Therapeutic duplication alerts**

The most frequent trigger for a duplication alert was the ordering of a different drug in the same therapeutic class as a medication already prescribed for a patient (n=229, 40.0% of duplication alerts). Other common triggers included prescribing a medication with a different formulation or strength to a medication already prescribed for that patient. Examples of the five most common duplication triggers are shown in table 6.

Half the duplication alerts (n=222, 49.3%) were triggered because a medication was prescribed that was identical to, or in the same therapeutic class as, a drug that had been ordered for a patient but had been ceased within the previous 24 h; that is, for half the duplication alerts, the ‘duplicated’ orders were not both active.

**Pregnancy alerts**

Twenty patients met the criteria set within the e-prescribing system for pregnancy alert triggers (ie, female and between 12 and 55 years of age). Of the 119 medications ordered for these patients, 43.3% triggered a pregnancy alert. Prescribers received on average five pregnancy alerts per female patient in the appropriate age range (range 1–10 alerts) and half the alerts (n=100, 49.7%) triggered for these patients were pregnancy alerts.

**DISCUSSION**

Previous research has focused on examining the extent to which alerts are ignored and the high rate of alerting resulting in alert fatigue.8–13 While studies have shown that users will often not use all available functionality of technological systems,16 17 we are not aware of any previous study which has demonstrated that this is a significant contributor to a new class of ‘technically preventable’ alerts. We found that prescribers did not use the e-prescribing system functions as intended, despite the functions’ potential to improve efficiency of work. As a consequence, clinically unnecessary alerts were generated, most likely adding to the frustration of prescribers. The time saving associated with use of the short-cut functions was lost to prescribers. Importantly, the generation of clinically unnecessary alerts potentially devalues alerts and confounds any attempt to assess alert effectiveness and impact. The hospital was unaware of the extent to which ‘technically preventable’ alerts were being generated as a result of prescribers not using the recommended short-cut functions. This may also be the case for e-prescribing systems in operation at other sites.

Computerized alerts were triggered in nearly a third of medication orders, with many orders triggering multiple alerts. Not surprisingly, interns, residents, and registrars encountered many more alerts than consultants, as the former groups ordered the majority of medications. We observed fewer alerts for orders generated by interns than registrars and residents, possibly because intern overrode fewer alerts than the more senior doctors. One might expect decision support to be of greater value for prescribers who are less familiar with the medications they are prescribing or the patient/condition for which they are prescribing.

**Table 4** Proportion of duplication alerts which could have been prevented with use of an e-prescribing system function

<table>
<thead>
<tr>
<th>e-Prescribing system function that could have prevented alert</th>
<th>Number (%) of preventable duplication alerts</th>
<th>% OF total duplication alerts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modify</td>
<td>108 (57.1)</td>
<td>18.9</td>
</tr>
<tr>
<td>AND</td>
<td>31 (16.4)</td>
<td>5.4</td>
</tr>
<tr>
<td>THEN</td>
<td>1 (0.5)</td>
<td>0.2</td>
</tr>
<tr>
<td>OR</td>
<td>1 (0.5)</td>
<td>0.2</td>
</tr>
<tr>
<td>Modify, AND</td>
<td>22 (11.6)</td>
<td>3.8</td>
</tr>
<tr>
<td>Modify, THEN</td>
<td>3 (1.6)</td>
<td>0.5</td>
</tr>
<tr>
<td>Other</td>
<td>23 (12.2)</td>
<td>4.0</td>
</tr>
<tr>
<td>Total</td>
<td>189 (100.0)</td>
<td>33</td>
</tr>
</tbody>
</table>

**Table 5** Examples of technically preventable and non-preventable duplication alerts

<table>
<thead>
<tr>
<th>Preventability of alert</th>
<th>Example trigger for a duplication alert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not technically preventable</td>
<td>Order #1: Oxycodone (5 mg) Tablet: 5 mg oral Four Times Daily</td>
</tr>
<tr>
<td></td>
<td>Order #2: Morphine (5 mg/1 ml) Injection: 5 mg (1 ml) subcutaneous PRN: minimum dosage interval 4 h</td>
</tr>
<tr>
<td></td>
<td>This alert could not have been prevented by a change in prescribing process, as the two active orders were for two different drugs (which belong to the same therapeutic class of opioid analgesics).</td>
</tr>
<tr>
<td></td>
<td>The prescriber ordered the STAT dose, then decided that an ongoing (regular) dose was also required. While the STAT dose remained active (ie, not yet administered or formally withheld), the regular order could have been generated from the STAT order by using the MODIFY/AND functions. This would have avoided the trigger of a duplication alert.</td>
</tr>
<tr>
<td>Technically preventable with use of e-prescribing system functions</td>
<td>Order #1: Movicol Powder for Oral Solution: 2 sachets oral STAT</td>
</tr>
<tr>
<td></td>
<td>Order #2: Movicol Powder for Oral Solution: 2 sachets oral In the Morning</td>
</tr>
<tr>
<td>Technically preventable with use of e-prescribing system functions (if first order was prescribed differently)</td>
<td>Order #1: Pantoprazole (40 mg) Injection: 40 mg intravenous In the Morning</td>
</tr>
<tr>
<td></td>
<td>Order #2: Pantoprazole (40 mg) E6 Tablet: 40 mg oral In the Morning</td>
</tr>
<tr>
<td></td>
<td>The patient had an existing active order for IV pantoprazole (Order #1), but the second prescriber wished to change this to oral tablets (Order #2). The duplication alert was triggered when the IV order was ceased and order #2 was placed. As the two formulations of pantoprazole were different, the alert could not have been prevented by the second prescriber. If however the first prescriber had selected pantoprazole (as drug) instead of Pantoprazole 40 mg Injection (as product) when ordering, the second prescriber would have been able to utilize the MODIFY function and avoid a duplication alert.</td>
</tr>
</tbody>
</table>
Frequent sub-optimal use of system functions suggests that either the efficient strategies are not known to users, that the strategies are known but system design features are poor, or the system functions are not viewed by users as beneficial or consistent with preferred prescribing practice, resulting in strategies not being used. Training may not have been sufficient to install a widespread understanding of the short-cut functions in MedChart and redesign of certain system functions may be necessary. For example, making functions more obvious or easier to use may result in increased adoption and interface design (e.g., layout of screen and controls) has been shown to guide users to select optimal strategies for a specific task. More importantly, the finding that doctors did not use the e-prescribing short-cut functions, despite the possible time saving and the avoidance of a computerized alert, indicates discordance between the prescribing task, as envisioned and performed by prescribers, and the underlying assumptions about the prescribing task reflected in the design of the system. For example, although the THEN function allows users to prescribe similar sequential orders together, saving the user up to 11 mouse clicks, prescribers may organize their thinking in terms of entering each order as an independent event, giving little attention to future medication orders until the first order-entry is complete. When designing a new system or technological application, one of the most important principles of user-centered design is consistency (in content, layout, and user cognition) between old and new systems; but several functions in the e-prescribing system designed to improve efficiency require clinicians to think about their prescribing tasks in different ways than when prescribing on paper. Technology creates new ways of doing things, it rarely maintains the old ways with the simple substitution of one medium for another, and prior experience of manual tasks can have a significant effect on the performance of computerized tasks. There is a tension between designing systems which replicate paper-based processes and thus may integrate more quickly into clinical practice, versus harnessing the advantage of technology to allow tasks to be completed in more efficient ways, but which requires a change in work processes and changes to cognitive processes which necessitate a greater level of training.

### Table 6 Examples for the five most common reasons a therapeutic duplication alert was triggered

<table>
<thead>
<tr>
<th>Duplication trigger</th>
<th>Number (% of total alerts)</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Different drug but same therapeutic class</td>
<td>229 (24.5)</td>
<td>Patient’s anti-ulcer medication was changed to a similar but different drug. Order #1: Esomeprazole (40 mg) Tablet: 40 mg oral In the Morning. Order #2: Omeprazole (20 mg) Tablet: 40 mg oral in the Morning.</td>
</tr>
<tr>
<td>Different formulation</td>
<td>145 (15.5)</td>
<td>Antifungal medication was changed from intravenous infusion to oral tablet. Order #1: Voriconazole (200 mg) Infusion: 200 mg intravenous Twice Daily. Order #2: Voriconazole (200 mg) Tablet: 200 mg oral Twice Daily.</td>
</tr>
<tr>
<td>Different schedule</td>
<td>78 (8.4)</td>
<td>Sleeping tablet was ordered as a single dose to be given immediately and for further doses as required. Order #1: Tempazepam (10 mg) Tablet: 10 mg oral STAT. Order #2: Tempazepam (10 mg) Tablet: 10 mg oral PRN: MDI=23 h.</td>
</tr>
<tr>
<td>Same order</td>
<td>38 (4.1)</td>
<td>Antibiotic was ordered on Day 1, ceased on the morning of Day 3, then re-ordered the same evening. Order #1: Metronidazole (400 mg) Tablet: 400 mg oral Three Times Daily. Order #2: Metronidazole (400 mg) Tablet: 400 mg oral Three Times Daily.</td>
</tr>
<tr>
<td>Different dose</td>
<td>24 (2.6)</td>
<td>Dosage of heart failure drug was increased during up-titration. Order #1: Carvedilol (3.125 mg) Tablet: 6.25 mg oral Twice Daily. Order #2: Carvedilol (12.5 mg) Tablet: 12.5 mg oral Twice Daily.</td>
</tr>
</tbody>
</table>

PRN means as required; STAT means immediately. MDI, minimum dose interval.

### Box 1 Duplication and dose range alerts triggered by the second of two orders for paracetamol tablets

**First order:** Paracetamol (500 mg) Tablet: 1 g oral PRN: minimum dosage interval 4 h: up to 4 doses per day.

**Second order:** Paracetamol (500 mg) Tablet: 1 g oral Four Times Daily.

The patient had an existing active order for PRN paracetamol (order #1), but the second prescriber wanted a regular four times daily order (order #2). A duplication alert was triggered when the drug product (Paracetamol (500 mg) Tablet) was selected for the second (regular) order. The duplication warning was overridden and the new regular order was activated. The first order also remained active. The patient then had two active orders (one regular and one PRN) for paracetamol, which could have led to a serious overdose (maximum dose is 4 g per 24 h; exceeding this will place the patient at risk of permanent liver damage). A dose range alert was therefore also triggered for paracetamol. The PRN order was not canceled until 17 h later (the following day).

This duplication alert potentially was clinically useful, as the MedChart regular order screen and PRN order screen cannot be viewed simultaneously. The two orders could only be viewed at the same time on the MedChart summary screen.

The duplication alert would not have been triggered if the second prescriber had MODIFIED the existing PRN order. This would have also automatically ceased the now obsolete first (PRN) order while generating the new regular order.

### Box 2 Local message that appears when the prescriber selects Oxycodone (could be replaced with a hyperlink ‘Advice on selecting appropriate form and brand’)

Please ensure the correct form and brand of Oxycodone is being prescribed:

**Tablets:**

- Oxycodone immediate release tablets (Endone)
- Oxycodone controlled (modified) release tablets (OxyContin)

**Capsules:**

May only be prescribed by the Pall Care and Acute Pain Service teams.

- Oxycodone immediate release capsules (OxyNorm).

Other forms of Oxycodone include:

- Oxycodone liquid (OxyNorm) — an immediate release product
- Oxycodone injection (OxyNorm Injection)

This rule is for information only.
There is value in alerting prescribers to the fact that a duplicated medication is being prescribed when the duplication has potential to result in patient harm (see box 1) as this has been shown to be a frequent prescribing error in hospitals.4 Therapeutic duplication alerts are frequently included in e-prescribing system alert sets, but limited evidence exists demonstrating their effectiveness.6 7 The high volume of duplication alerts overall in our study suggests that the firing threshold may be too low. It is interesting to note that more than half of all the duplication alerts would not have triggered if the system was reconfigured so that alerts only fired when the two medication orders were active at the same time. By maintaining the 24 h time frame for certain medications only, such as gentamicin (where a second dose in within 24 h of a once daily dosing regimen would pose a significant risk of toxicity) or colchicine (which carries a risk of cumulative toxicity due to its low therapeutic index), a large proportion of duplication alerts would be eliminated.

For female patients aged 12–55 years, pregnancy alerts were triggered more frequently than any other alert type. Ideally, a prescriber should be able to enter a patient’s pregnancy status into the system (just as they currently do for a patient’s allergy status) so that if the patient is not pregnant, pregnancy warnings do not fire. Alternatively, pregnancy alerts for an individual patient who is not pregnant could be suppressed for the duration of that particular hospital stay when a user overrides the first pregnancy alert, a strategy known to reduce repeat alerts.13

One quarter of the alerts we identified were local messages. These messages are currently presented to prescribers in an identical fashion to other safety alerts, but the majority of hospital messages offer doctors advice about the medication being selected (see box 2) rather than warning prescribers about a safety critical event. Low priority alerts have been shown to cause user frustration and slow down the medication ordering process.25 Research has shown that interrupting prescribers for only the most serious warnings is an effective strategy for increasing alert acceptance rates.26 To reduce alert fatigue, most local hospital messages could be removed and presented to prescribers in a non-interruptive fashion. For example, the alert shown in box 2 could be replaced with the hyperlink that appears in the box caption. These hyperlinks could appear on the prescribing screen, not on a separate alert screen that interrupts the prescriber and needs to be clicked past. The presentation of additional text on a portion of the usual prescribing screen would give prescribers direct access to information with minimal interruption to workflow.27

It is not surprising that medications ordered to be administered when required (ie, PRN) were more likely to carry an alert than other schedules of medications. PRN orders are less likely to be ceased, as they remain active ‘in case’ required. They are also often listed as an alternative to a regular medication, or as a stronger option. For example, a patient may be prescribed oxycodone tablets as a regular order, with ‘add-on’ PRN oxycodone or PRN morphine injection for breakthrough pain. Oxycodone and morphine, both opioid analgesics, each trigger a duplication alert when the other is ordered. Oxycodone (which also triggers a local message alert) carried more alerts than any other medication, followed by morphine, paracetamol (all analgesics), and then temazepam (for sleep). These drug types pose specific challenges when designing decision support rules.

Limitations of the study

Only orders with alerts that were ‘overridden’ by prescribers were available for review as the system did not log orders abandoned following an alert. Given the value of being able to monitor alert generation and its consequences on prescribing behavior, organizations implementing e-prescribing systems should specify the logging and reporting of these data by vendors. The lack of these data limited our ability to assess the extent to which alerts were effective in changing prescribers’ orders. However, our previous observational work undertaken during ward rounds suggests that the proportion of orders abandoned or changed as a result of the current alerts in the system is small.14 Thus we hypothesize that the results presented here are largely representative of all alerts triggered in the system. In this study, we only reviewed orders generated using one e-prescribing system, but as the alerts we examined are typical of those encountered by clinicians using other e-prescribing systems, our findings may provide generic lessons for a range of systems.

CONCLUSION

A detailed analysis of safety alerts revealed that modifications to the mechanisms underlying alert generation, and to the alert types chosen by designers to be displayed, are needed to ensure that prescribers are presented with fewer but more meaningful computerized alerts. Importantly, this is the first study to examine how use of e-prescribing system functions may influence alert generation. Prescribers often did not use the e-prescribing system short-cut functions, despite the functions’ potential to improve efficiency of work. This finding indicates discordance between the prescribing task, as performed by prescribers, and the underlying assumptions about the prescribing task reflected in the design of the system. Designs which aim to improve the efficiency of the prescribing process but which do not align with the cognitive processes of users may fail to achieve this desired outcome and produce unexpected consequences such as triggering clinically unnecessary alerts and user frustration. The generation of clinically unnecessary alerts also potentially confounds any attempt to assess alert effectiveness and impact. Developers of decision-support systems should test the extent to which technically preventable alerts may arise when prescribers fail to use system functions as designed.

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