Reasons for Computerized Provider Order Entry (CPOE)-based Inpatient Medication Ordering Errors: An Observational Study of Voided Orders

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ABSTRACT

Objective: Medication voiding is a CPOE-based discontinuation mechanism that allows clinicians to identify erroneous medication orders. We investigated the accuracy of voiding as an indicator of clinician identification and interception of a medication ordering error, and investigated reasons and root contributors for medication ordering errors.

Method: Using voided orders identified with a void alert, we conducted interviews with ordering and voiding clinicians, followed by patient chart reviews. A structured coding framework was used to qualitatively analyze the reasons for medication ordering errors. We also compared clinician-CPOE-selected (at time of voiding), clinician-reported (interview), and chart review-based reasons for voiding.

Results: We conducted follow up interviews on 101 voided orders. The Positive Predictive Value (PPV) of voided orders that were medication ordering errors was 93.1% (95% CI 88.1-98.1%, *n*=94). Using chart review-based reasons as the gold standard, we found that clinician-CPOE-selected reasons were less reflective (PPV=70.2%, 95% CI 61.0-79.4%) than clinician-reported (interview) (PPV=86.1%, 95% CI 78.2-94.1%) reasons for medication ordering errors. Duplicate (*n*=44) and improperly composed (*n*=41) ordering errors were common, often caused by predefined order sets and data entry issues. A striking finding was the use of intentional violations as a mechanism for notifying and seeking ordering assistance from pharmacy service. Nearly half of the medication ordering errors were voided by pharmacists.

Discussion: We demonstrated that voided orders effectively captured medication ordering errors. The mismatch between clinician-CPOE-selected and the chart review-based reasons for error emphasize the need for developing standardized operational descriptions for medication ordering errors. Such standardization can help in accurately identifying, tracking, managing, and sharing erroneous orders and their root contributors between healthcare institutions, and with patient safety organizations.

Keywords

Medication errors, patient safety, CPOE, medication order voiding

BACKGROUND AND SIGNIFICANCE

Medication errors are reported to cause approximately 1.5 million preventable adverse drug events in the United States every year [1]. Electronic prescribing using computerized provider order entry (CPOE) systems has been highlighted by clinicians, researchers, and policy makers as a mechanism to prevent and mitigate potential medication errors [2, 3]. Improvements in medication safety are achieved through CPOE infrastructures that support coordination of clinical tasks among patient care teams [4], reduction of misinterpretation of orders [5], minimization of illegible orders [6], assistance with medication dosage calculations [7], and decision support using alerts (e.g., drug-drug interaction alerts, drug allergy alerts, patient problem-based indication alerts, and dosage suggestions) [7-9].

Notwithstanding these advantages, several concerns associated with CPOE use continue to surface including unintended consequences of CPOE use [10, 11], adverse drug events [12], and other medication safety challenges [8, 13]. With over 26.1% (range: 16.0-53.6%) of medication orders in acute care hospitals in the United States initiated using a CPOE system [14], the importance of devising effective mechanisms to identify, characterize, and track medication ordering errors are of significant concern. The value of recording and tracking medication errors has been highlighted in an Institute of Medicine (IOM; now, the National Academy of Medicine) Committee report, Health IT and Patient Safety: Building Safer Systems for Better Care [15], and in the 2014 United States Food and Drug Administration Safety and Innovation Act (FDASIA) [16]. Furthermore, medication safety experts have emphasized the "worrisome lack of effort to learn from medication ordering errors" and characterized the current state of unsafe medication ordering practices to be "still a work in progress"[17]. This is especially important given the high rates of preventable adverse drug events (pADEs) that occur during medication

ordering [18, 19]. For example, Nebeker et al. [20] reported that 61% of pADEs occurred during the medication ordering stage.

To address this, recent initiatives have focused on ways to identify and classify medication ordering errors [21]. However, there are limited, if any, approaches for automatically flagging, tracking, and aggregating medication ordering error data in real-time.

Informed by a recent retrospective analysis of CPOE-based medication orders, we identified a potentially viable approach for identifying intercepted erroneous medication orders. This approach relies on tracking medication orders that were discontinued using the "void" function, indicating that an order was in error (detailed description is provided in the section on "Medication Order Voiding") [22]. Based on a retrospective study of nearly 6 million medication orders over a 6-year period, Kannampallil and colleagues found that an estimated 70% of voided orders were medication ordering errors [23]. However, clinician-selected reasons documented at the time of voiding were reasonably predictive of the actual cause of medication ordering errors only for duplicate orders (72%), but not for any of the other menu of choices for voided order error reasons.

Leveraging these results, we sought to better characterize the underlying causes, and reasons for medication ordering errors identified through the medication voiding process. For voided orders, using an observational study, we asked the following research questions: (a) What are the reasons for CPOE-based medication ordering errors based on clinician perceptions, and patient chart reviews? (b) Are there mismatches between clinician perceived reasons (based on interviews) and actual reasons (based on chart reviews) for these errors? (c) What factors contribute to the generation of, and identification of medication ordering errors?

MEDICATION ORDER VOIDING

Medication order voiding is a CPOE-integrated discontinuation function in the Cerner

Electronic Health Record (EHR) that allows clinicians to identify and remove erroneous orders

from a patient's active medication list [22, 23]. By choosing to void a medication, a clinician

indicates that an order was erroneously placed. Within the CPOE, medication order voiding

involves the selection of a medication order to be voided, and choosing the "void" option. After

this, the clinician is prompted to select from one of eight choices as their reason for voiding:

blank (no reason is provided), order on wrong encounter, wrong patient, incorrect ordering

physician, duplicate order, system date error, voiding student order, and improperly composed

order (see Appendix Figure 1 for the voiding workflow). This set of eight reasons were the

default, vendor-provided options at the time of CPOE implementation. We refer to these as the

"clinician-CPOE-selected reasons for voiding." Although clinicians have multiple options to

discontinue medication orders, including "cancel," "modify," or "complete," the "void" function

is intended to be used for medication orders that a clinician identifies and flags as being placed in

error (e.g., order on the wrong patient or wrong drug). Evaluation of such voided orders thus can

provide insights into the nature, reasons, and causes of medication ordering errors.

METHOD

Setting

This study was conducted at a Midwestern academic medical center in the United States that

houses a 495-bed hospital with approximately 22,000 hospitalizations per year. Medication

orders were placed with a CPOE using Cerner Powerchart®. The configuration of Cerner at this

site included the use of Multum drug-drug interaction and duplicate order alerts, along with

clinical decision support for drug-laboratory (e.g., when ordering potassium or an ACE

(angiotensin converting enzyme) inhibitor, serum potassium test results are evaluated), drug-diet, and drug-disease alerts.

Physicians (attending, fellows, and residents), pharmacists, nurses, and medical students can place medication orders. As per state laws, pharmacists and nurses can place medication orders based on verbal, written, or protocol-based physician orders. Although a physician co-signature is required, these orders are immediately actionable. Medication orders placed by medical students are not actionable without a physician co-signature.

Medication voiding data was collected from inpatient units, the setting where most of the preventable prescribing errors have been reported [24]. Recent IOM reports have suggested that a hospitalized patient experiences an average of 1 medication error per day during their stay [25, 26]. Additionally, due to the longitudinal nature of care provided in inpatient units, it was relatively easier to contact clinicians who were voiding medication orders on hospitalized patients.

This study was approved by the institutional review board of the University, and verbal consent was obtained from all participants.

Void Alert Tool

For identifying and tracking inpatient voided orders, we developed a Void Alert Tool (VAT). VAT generated an alert based on the following conditions: (a) voiding action performed by a clinician for a patient in an inpatient unit, (b) for a patient whose age >18 years.

Each VAT trigger initiated a secure email transferring the details of the voided order—Medical Record Number, patient name, medication name, ordering clinician, and voiding

clinician—to the clinical inbox of the first author (JA). A void alert secure message for a test patient is shown in Appendix Figure 2.

Data Collection

We followed-up on a convenience sample of 289 voided orders (37%), mostly between the hours of 7AM to 6PM during week days (Monday through Friday). Follow up interviews were conducted on 101 voided orders.

Clinician Interviews

Within 24 hours of a VAT trigger, a researcher attempted to contact the clinicians—both the original ordering clinician (i.e., clinician who placed the order that was later voided), and the voiding clinician (i.e., clinician who voided the original order)—through the hospital paging system and telephone calls.

Clinicians who responded to the page with telephone calls were recruited for participation in this study. Recruited clinicians were interviewed using a semi-structured interview template. The primary purpose of the follow up telephone interview was to develop a contextual perspective on the medication order and its subsequent voiding by obtaining first-hand reports from the involved clinicians. Similar approaches have been successfully used for prospectively studying medication ordering errors [13].

For the ordering clinician, interview questions focused on the characteristics of the medication order, reasons for placing the original order, possible reasons for its eventual voiding, and factors that could have led to the order being voided. For the voiding clinician, interview questions were related to the reasons for their voiding, how they reached their voiding decision, and potential factors that led to the voiding of the order. In some cases, where the ordering and voiding

clinician was the same individual, questions were modified to gather insights on reasons for both ordering and voiding. Interviews lasted approximately 5-7 minutes and were audio-recorded. All interviews were conducted either by a medical student or a physician-researcher. The interview guide is provided in section 2 of the Appendix.

Patient Chart Reviews of Voided Orders

Patient charts of all voided orders that had an interview with at least one clinician (n=101 voided orders) were reviewed. The purpose of the chart review was to: (a) identify whether a voided medication order was an error, and (b) if it was an error, the reason for the error (we refer to this as "medication ordering error reason (chart)").

For characterizing a medication ordering error, we used the following generic definition: "any preventable event that may cause or lead to inappropriate medication use or patient harm" [27]. Specifically, we investigated whether any signed voided order may have resulted in (or led to) inappropriate medication use or harm. The reviewers relied mainly on progress notes, other medication orders, problem lists, and laboratory tests to make this determination. We used the chart review findings as the gold standard basis for all comparisons. Prior research, based on a systematic review, has shown that chart review-based evaluation is used extensively to identify medication related problems [28].

Chart reviews were conducted in two phases by trained chart abstractors, using an abstraction protocol for determining (a) and (b) described above; the difference between the phases was that additional demographic data was captured in the first phase. In the first phase, a physician (SS) reviewed patient charts associated with each voided order to determine (a) and (b) for each voided order. This reviewer also gathered the following data elements from the patient chart: clinician role for both ordering and voiding (physician, nurse, pharmacist, medical student), time

of ordering and voiding, patient demographics (age, gender, and race), and medication details (name, route, dosage, and frequency of use).

In the second phase, a clinical pharmacist and a physician (CRF, WLG; reviewing 50 and 51 charts respectively) independently reviewed each voided order to determine (a) and (b) for each order. In case of disagreements between the first and second phases on either (a) or (b), a third adjudicator independently reviewed the chart, and a final disposition was based on a majority decision among the three reviewers. The reviewers had access to the entire patient chart during the reviews. The data collection process is illustrated in Figure 1.

[Insert Figure 1 here]

Data Analysis

Analysis of Interviews

Interviews were transcribed verbatim and deductively analyzed using the structured framework developed by Schiff et al. [21]. The framework included three themes: what happened, why it happened, and possible prevention strategies. The "what happened" theme was used to categorize the clinician-reported reasons for voiding during the interview. We refer to these as "clinician-reported reasons for voiding (interview)"; "why it happened" theme was used for coding the contributing factors for the order and its eventual voiding; and finally, "prevention strategies" were the suggestions provided by clinicians for preventing similar medication ordering errors.

We further classified clinician-reported reasons (interview) along two dimensions: first, along four core categories representing the primary factors contributing to the medication ordering errors: CPOE order entry issues, user-related issues, system limitations, and transition issues.

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Next, for each core category, we identified specific sub-categories. For example, user-related issues were further coded into sub-categories such as data entry errors, lack of user clinical knowledge, and communication issues. The categories and sub-categories were adapted from published frameworks on reasons for medication errors [21, 29]. Descriptions for the core and sub-categories are provided in Table 1.

[Insert Table 1 here]

Initial coding of the interview data was performed by the third and fourth authors (AJ, SS) and all coding was independently (i.e., blinded from initial coding) performed by the first author (JA). Any discrepancies between the coders were discussed (less than 5%) and 100% consensus was reached.

Statistical Analysis

We first determined the positive predictive value (PPV) of voided orders that were actual medication ordering errors (from chart review) and its 95% confidence interval. A standard error of proportions (SEP) was also determined.

We also investigated mismatches between the clinician-CPOE-selected, clinician-reported (interview), and medication ordering error reasons (chart) (see detailed descriptions of each in Table 2). Using the chart review-based error reasons as the gold standard, we determined the PPV of similarity in the reasons between: clinician-CPOE-selected reasons and medication ordering error reasons (chart); and, clinician-reported reasons (interview) and medication ordering error reasons (chart). PPVs were computed based on the number of medication ordering errors identified from chart review.

[Insert Table 2 here]

RESULTS

During the 6-month study period (January 27, 2016 to July 29, 2016), a total of 787 void alerts were generated (4.3 alerts per day). The overall rate of medication order voiding was 0.21% during this period (787 voided orders among 377,480 inpatient medication orders for patients >18 years of age).

Interviews were conducted on 101 voided orders: for 95 voided orders, interviews were conducted with at least the voiding clinician; six orders had interviews with just the ordering clinician. 80 unique clinicians were interviewed: 30 physicians, 28 pharmacists, and 22 nurses. A detailed summary of the sample characteristics is provided in section 3 of the Appendix.

Reasons for Medication Ordering Errors

Based on chart reviews of 101 voided orders, the PPV of voided orders that were medication ordering errors was 93.1% (95% CI 88.1-98.1%, *n*=94 erroneous orders out of 101 voided orders; i.e., 7 of the voided orders were not medication ordering errors). The predominant reasons for medication ordering errors for 94 orders identified as medication ordering errors were duplicate orders (*n*=44), followed by improperly composed orders (*n*=41), wrong drug (*n*=3), wrong encounter (*n*=2), voiding student order (*n*=2), wrong patient (*n*=1), and wrong time selected (*n*=1). Definitions for these error reasons is provided in Appendix Table 6.

For the 94 medication ordering errors, we also describe the clinician-CPOE-selected reasons and clinician-reported reasons for voiding (interview). For the clinician-CPOE-selected reasons, the most prevalent reason was duplicate order (*n*=58), followed by improperly composed order (*n*=25), voiding student order (*n*=6), wrong patient (*n*=4), and incorrect ordering physician (*n*=1).

For clinician-reported reasons for voiding (interview) contributing to medication ordering errors, clinicians attributed the reason for voiding as duplicate order (n=43), improperly composed order (n=38), wrong drug (n=5), wrong encounter (n=2), discontinuation issues (n=1), delays in order processing (n=1), voiding student order (n=1), wrong patient (n=1), incorrect ordering physician (n=1), and wrong time selected for order (n=1). A summary of the error reasons using the three data sources is provided in Figure 2 (additional data is also provided in Appendix Table 5).

[Insert Figure 2 here]

Comparing the Reasons for Medication Ordering Errors

Using the chart review-based reasons as the gold standard for comparison, we found that the PPV of similarity between clinician-CPOE-selected reasons and chart review was 70.2% (95% CI 61.0-79.4%); PPV between clinician-reported reasons (interview) and chart review was 86.1% (95% CI 78.2-94.1%). We found no significant association between clinician-CPOE-selected and clinician-reported (interview) reasons (χ^2(1) =2.95, p=0.086).

Factors leading to Medication Ordering Errors

Based on interviews, we identified several contributing factors for each of the reasons for medication ordering errors (See Table 1 for the list of core and sub categories).

The primary factors that contributed to the medication ordering errors were user-related issues (57%, n=54) and order entry process-related issues (31%, n=29); followed by system limitations (10%, n=9), and transition issues (2%, n=2). Among these, user-related issues were predominantly caused by data entry errors (37%, n=20 of 54), creation of multiple orders by multiple clinicians (26%, n=14 of 54), and lack of clinical knowledge (13%, n=7 of 54).

Meanwhile, order entry issues were triggered by visual interface issues (48%, n=14 of 29) and pre-defined order sets or medication protocol issues (38%, n=11 of 29).

We organized these factors under the various chart-based medication ordering errors (See Appendix Table 6). Duplicate ordering errors were caused primarily by order entry (50%, n=22 of 44) and user-related issues (45%, n=20 of 44). Order entry issues arose as a result of CPOE user interface or order set template challenges. During interviews, clinicians stated that at the time of entry of medication orders, they were unable to view the complete list of active medication orders to ascertain duplication. One clinician remarked that *"because originally I didn't see that the order was placed. So, I ordered it before I tried to send him [patient] upstairs, and as I was charting it I saw it was already ordered this morning, so I voided it. I ordered it and it was a duplicate because I didn't realize it was already ordered."* With regards to the order set/template issues, duplicate orders were placed because clinicians failed to remove selections of medications (i.e., by unchecking boxes) that were included in an order set profile. As one participant stated "*...a lot of it has to do with duplicate orders, a lot of it has to do with just not checking a box [i.e., by selecting a checkbox] in the whole order set. Because when they go in, they will check what they want but they won't uncheck [i.e., by removing unnecessary checkbox selections] what's already on the profile*."

User-related issues contributing to duplicate orders were related to multiple clinicians placing the same medication order. This was often the case when clinicians working in a team were unaware of the other team members' orders on their patients. This was exemplified by a voiding clinician who stated that *"It [medication order] was the same thing, duplicate orders, two physicians ordered the same product. They obviously are not paying attention on what the other one is ordering*."

Similar to duplicate ordering, medication ordering errors related to improperly composed orders were caused predominantly by user-related workflow and process issues (70%, *n=*29 of 41 improperly composed ordering errors), with approximately half of these being data entry errors. A voiding clinician stated: "*I voided that order because I accidently wrote it as not a PRN [pro re nata] as to administer or as scheduled, and the second I hit send I realized that I did that, so I immediately copied the order, voided the old one, and changed it to a PRN.*"

As previously described, we had a limited number of wrong drug, wrong encounter, wrong patient, voiding student order and wrong time ordering errors within our sample. A brief description of the errors, their frequencies, and examples are provided in Appendix Table 6.

Factors leading to Medication Ordering Error Detection and Interception

Besides the factors contributing to the generation of medication ordering errors, we also gathered insights from voiding clinicians on factors and strategies leading to their timely identification and interception. One of the interesting findings from our interviews was the surveillance role of inpatient pharmacists in the interception of ordering errors (*n=*48 by pharmacists). For instance, a pharmacist stated that: "*I voided it [medication order] after I spoke to the APN [Advance Practice Nurse] because we have the credit [payment], they just entered it as a non-formulary medication when they should have ordered it through the respiratory care pathways, it was not properly ordered. I look at orders all day...*" In another instance, a pharmacist voided a medication order for heparin because: "*there were two separate orders for heparin around the same timeframe so I just voided one of the duplicate orders, because it's part of a protocol that they do and part of order sets so that one tends to be duplicate ordered on a pretty regular basis.*"

Closely related to the pharmacists' surveillance function was their beneficial role to clinicians as a workaround mechanism for medication ordering. In a number of cases, physicians placed improperly composed orders (e.g., an extremely large dose), with the expectation that pharmacists would intercept these "intentional violations" [30] and enter the appropriate medication order. One of the pharmacists described an instance of intentional violation as follows: *"physician entered an order that did not make sense. It was 1% dextrose, it's not something we made in the pharmacy, it was never dispensed to the patient. What the physician was trying to do was let us know that she wanted us to write the TPN [Total Parenteral Nutrition] order and that was her way to alert us. It was an impossible order; we would never have made that solution... I voided it so that the patient would not get charged for it. She wanted us, the pharmacist, to place the order, so I put in the appropriate order."*

DISCUSSION

Our review of voided orders was facilitated by an automated void alert tool, which helped in identifying and investigating potential medication ordering errors. The PPV of medication ordering errors among void alerts was high (93%), translating to approximately 4 intercepted medication ordering errors per day. There was nearly 86% concordance between clinician interviews and chart review regarding the reasons for these errors. However, as described in prior research, clinician-CPOE-selected voiding reasons for medication ordering errors did not correlate with their verbally reported reasons or those found in charts [23]. This worrisome mismatch could be due to limited choices available on the CPOE drop-down list of reasons. Alternatively, it also suggests that voiding clinicians either lacked a good understanding or were not careful in their drop-down selections. This discrepancy points to the need for improved taxonomy/choices for characterizing medication ordering errors within the voiding process.

Developing standardized operational descriptions of the reasons for voiding can help in better understanding, ascertaining and sharing of medication ordering errors and their root contributors among local and national patient safety organizations [23, 31].

Consistent with prior research, the leading underlying causes for errors related to CPOE ordering were entry process errors and user issues, resulting from a complex set of human factors, usability, and system-related challenges [7, 17, 21, 29, 32-34]. Similar to Wetterneck et al. [32], we also found that duplicated ordering errors were common; primarily caused by order entry process-related issues from predefined order sets and partial visual displays of active medication lists. Efforts to improve such usability issues with order sets and interface screen layouts are ongoing [13, 29, 35-39].

A novel insight from this study was the uncovering of intentional violations. Several clinicians described deliberately composing incorrect or improper orders for the purpose of obtaining assistance from pharmacists for identifying the right dosage, type or form for a drug, or solution such as hyperalimentation. Such ordering workarounds represent deviations from expected or standard operating procedures [30, 40]. The Quality in Australian Health Care Study found that deliberate violation workarounds caused up to 4.8% of adverse events; however, it is unknown how many of these events were related to medications [41]. Although most of these violation workarounds did not cause patient harm, they remain a source of concern as local attitudes, motivations, procedures, and technological systems allow (and, perhaps drive) them to occur [30, 42]. These intentional violations also underscore the critical surveillance role played by clinical pharmacists in inpatient settings that has been highlighted in prior research [19, 43, 44].

Using void or equivalent functions, clinicians can easily document intercepted errors within their clinical workflow, and correspondingly add metadata regarding the identified error. Based

on informal discussions with users and administrators of prominent EHR systems, the voiding function or a closely related functionality is available in both Cerner and Epic EHRs. The outpatient Longitudinal Medical Record system at Partners Healthcare has a similar functionality labeled as "Error (erroneous entry)." It must, however, be noted that such functions are optional, and are not enabled at all institutions or installations [23].

The void function can easily be turned-on across institutions to capture and record medication safety data, without disrupting the clinical workflows. The voided order dataset can be used to complement other error reports for understanding the rates and reasons for medication errors and for tailoring surveillance mechanisms. In addition to formalizing the reasons for medication ordering errors, it is also likely that clinician education may help with streamlining the process of medication voiding and the accuracy of the selected reasons for voiding. With a growing emphasis on the need for a culture of safety to create learning health systems, clinicians may be engaged to provide more accurate reasons for voiding that can benefit their own work as well as others in the institution.

The limitations of our study highlight the challenges of capturing highly contextual, real-time data on CPOE use and medication errors. As this study was conducted a single academic medical center using a single EHR, the findings may not translate to other settings or EHR systems. Nevertheless, we believe that the insights on the reasons for medication ordering errors identified through voiding is generalizable to other systems. The response rate to our efforts to contact clinicians was only 37%, which is substantial, but clearly imperfect. This was likely due to several factors. First, given the real-time nature of this study, we had considerable difficulty in reaching certain clinicians (especially pharmacists and nurses) who did not carry pagers, or did not respond. In other cases, nurses or pharmacists had left the unit by the time we attempted to

contact them. Additionally, we did not follow up on voided orders that were placed >24 hours earlier, causing more sampling of voided orders from Sunday through Thursday. Due to the retrospective nature of interviews, there is a possibility that some of the clinicians may have misquoted or failed to recall their reasons for voiding. However, all follow up calls included in our dataset were made within a 24-hour period, potentially minimizing this limitation.

There were several instances of the same clinician performing the multiple voiding tasks for the same patient. In these cases, interview follow up was based on the first voided order. This resulted in a loss of approximately 10% of the voided orders. In 36 orders, the ordering and voiding clinician were the same. In these cases, the participant was asked the set of questions provided in Appendix Section 2 (see questions under "interview guide for same voiding and ordering clinician"). Although we did not perform any analysis on this sub-group of interviews, there were no observable differences between these and other interviews.

Chart reviewers were not blinded to the clinician-CPOE-selected reasons for voiding, which may have caused a bias. However, based on our prior research, we found that the clinician-CPOE-selected reasons were not indicative of the actual reasons for medication ordering errors [23]. Hence, during the chart review training, we had instructed chart reviewers not to rely on the clinician-CPOE-selected reasons (present in the order details of the patient's chart) during their review.

Finally, as previously mentioned, "void" is one of multiple ways clinicians can discontinue erroneous medication orders (cancel, modify, or complete being other options). Hence, use of the "void" function is dependent on the clinician awareness and willingness to use it. Although our previous study [23] showed widespread awareness and use among clinicians, it is likely that clinicians also used other mechanisms to discontinue erroneous medication orders.

In spite of these limitations, our study demonstrates the value of near-real time identification of medication ordering errors and interviewing the clinicians involved to gather perspectives on the process of medication ordering error creation to interception.

CONCLUSION

Tracking medication order voiding using alerts can provide a potential mechanism for identifying, investigating, and tracking medication ordering errors. We found that timely follow up with clinicians on the contributing causes for ordering errors can help in developing a more robust taxonomy of its voiding reasons, and in developing interventions that can mitigate CPOE-related challenges. Medication voiding function provides a viable reporting mechanism to develop a generalizable and standardized set of CPOE-based medication ordering error reasons that can be adopted and shared across healthcare institutions and patient safety organizations. Additionally, the surveillance role of pharmacists for monitoring inpatient orders, and mechanisms to prevent intentional violations are interesting topics that require further investigation.

CONTRIBUTORS' STATEMENTS

[removed for anonymity].

REFERENCES

1. Bates DW. Preventing medication errors: a summary. American Journal of Health-System Pharmacy 2007;**64**(14):S3-S9.

2. Gandhi TK, Weingart SN, Borus J, et al. Adverse drug events in ambulatory care. New England Journal of Medicine 2003;**348**(6):1556-64.

3. Kaushal R, Kern LM, Barrón Y, et al. Electronic prescribing improves medication safety in community-based office practices. Journal of General Internal Medicine 2010;**25**(6):530-36.

4. Potts AL, Barr FE, Gregory DF, et al. Computerized physician order entry and medication errors in a pediatric critical care unit. Pediatrics 2004;**113**(1):59-63.

5. Cordero L, Kuehn L, Kumar RR, et al. Impact of Computerized Physician Order Entry on Clinical Practice in a Newborn Intensive Care Unit. Journal of Perinatology 2004;**24**(2):88-93.

6. Ash JS, Sittig DF, Poon EG, et al. The Extent and Importance of Unintended Consequences Related to Computerized Provider Order Entry. Journal of the American Medical Informatics Association : JAMIA 2007;**14**(4):415-23 doi: 10.1197/jamia.M2373published].

7. Slight SP, Eguale T, Amato MG, et al. The vulnerabilities of computerized physician order entry systems: a qualitative study. Journal of the American Medical Informatics Association 2015;**23**(2):311-16.

8. Bates DW, Leape LL, Cullen DJ, et al. Effect of computerized physician order entry and a team intervention on prevention of serious medication errors. Journal of the American Medical Association 1998;**280**(15):1311- 16.

9. Galanter WL, Bryson ML, Falck S, et al. Indication Alerts Intercept Drug Name Confusion Errors during Computerized Entry of Medication Orders. PloS ONE 2014;**9**(7):e101977.

10. Campbell EM, Sittig DF, Ash JS, et al. Types of unintended consequences related to computerized provider order entry. Journal of the American Medical Informatics Association 2006;**13**(5):547-56.

11. Ash JS, Sittig DF, Dykstra R, et al. The unintended consequences of computerized provider order entry: findings from a mixed methods exploration. International journal of medical informatics 2009;**78**:S69-S76.

12. AHRQ Patient Safety Network. Computerized Provider Order Entry. Secondary Computerized Provider Order Entry 2015. http://psnet.ahrq.gov/printviewPrimer.aspx?primerID=6.

13. Koppel R, Metlay JP, Cohen A, et al. Role of computerized physician order entry systems in facilitating medication errors. Journal of the American Medical Association 2005;**293**(10):1197-203.

14. Radley DC, Wasserman MR, Olsho LE, et al. Reduction in medication errors in hospitals due to adoption of computerized provider order entry systems. Journal of the American Medical Informatics Association 2013;**20**(3):470-76.

15. Chou D. Health IT and patient safety: building safer systems for better care. Journal of the American Medical Association 2012;**308**(21):2282-82.

16. US Food and Drug Administration. FDASIA Health IT Report: Proposed Strategy and Recommendations for a Risk-based Framework 2014.

17. Schiff GD, Hickman TT, Volk LA, et al. Computerised prescribing for safer medication ordering: still a work in progress. BMJ Quality & Safety 2016;**25**:315-19.

18. Bates DW, Boyle DL, Vander Vliet MB, et al. Relationship between medication errors and adverse drug events. Journal of General Internal Medicine 1995;**10**(4):199-205.

19. Kaushal R, Shojania KG, Bates DW. Effects of computerized physician order entry and clinical decision support systems on medication safety: a systematic review. Archives of internal medicine 2003;**163**(12):1409-16.

20. Nebeker JR, Hoffman JM, Weir CR, et al. High rates of adverse drug events in a highly computerized hospital. Archives of Internal Medicine 2005;**165**(10):1111-16.

21. Schiff GD, Amato MG, Eguale T, et al. Computerised physician order entry-related medication errors: analysis of reported errors and vulnerability testing of current systems. BMJ Quality & Safety 2015;**24**:264-71 doi: 10.1136/bmjqs-2014-003555published].

22. Cerner. uCern. Secondary uCern 2016. https://wiki.ucern.com/pages/viewpageattachments.action?pageId=1067811766.

23. Kannampallil TG, Abraham J, Solotskaya A, et al. Learning from Errors: Analysis of Medication Order Voiding in CPOE Systems. Journal of the American Medical Informatics Association 2017 doi: https://doi.org/10.1093/jamia/ocw187published].

24. Dean B, Barber N, Schachter M. What is a prescribing error? Quality in Health Care : QHC 2000;**9**(4):232-37 doi: 10.1136/qhc.9.4.232published].

25. Aspden P, Wolcott J, Bootman JL, et al. *Preventing medication errors: quality chasm series*: National Academies Press, 2006.

26. Institute of Medicine. Preventing Medication Errors In: Committee on Identifying and Preventing Medication Errors Board on Health Care Services, ed. Institute of Medicine, 2006.

27. National Coordinating Council for Medication Error Reporting and Prevention. NCC MERP Taxonomy of Medication Errors. In: MERP N, ed. Taxonomy of Medication Errors, 2001.

28. Manias E. Detection of medication-related problems in hospital practice: a review. British Journal of Clinical Pharmacology 2012;**76**(1):7-20.

29. Brown CL, Mulcaster HL, Triffitt KL, et al. A systematic review of the types and causes of prescribing errors generated from using computerized provider order entry systems in primary and secondary care. Journal of the American Medical Informatics Association 2017;**24**(2):432-40.

30. Amalberti R, Vincent C, Auroy Y, et al. Violations and migrations in health care: a framework for understanding and management. Quality and Safety in Health Care 2006;**15**(suppl 1):i66-i71.

31. Amato MG, Salazar A, Hickman TT, et al. Computerized prescriber order entry–related patient safety reports: analysis of 2522 medication errors. Journal of the American Medical Informatics Association 2017;**24**(2):316-22.

32. Wetterneck TB, Walker JM, Blosky M, et al. Factors contributing to an increase in duplicate medication order errors after CPOE implementation. Journal of the American Medical Informatics Association 2011;**18**(6):774-82.

33. Patel VL, Kannampallil TG. Cognitive informatics in biomedicine and healthcare. Journal of Biomedical Informatics 2015;**53**:3-14.

34. Patel VL, Kannampallil TG, Shortliffe EH. Role of cognition in generating and mitigating clinical errors. BMJ Quality & Safety 2015;**24**(7):468-74.

35. Khajouei R, Jaspers MWM. The impact of CPOE medication systems' design aspects on usability, workflow and medication orders. Methods of Information in Medicine 2010;**49**(1):3-19.

36. Thiel SW, Asghar MF, Micek ST, et al. Hospital-wide impact of a standardized order set for the management of bacteremic severe sepsis. Critical care medicine 2009;**37**(3):819-24.

37. Horsky J, Kuperman GJ, Patel VL. Comprehensive analysis of a medication dosing error related to CPOE. Journal of the American Medical Informatics Association 2005;**12**(4):377-82.

38. Khajouei R, Peek N, Wierenga PC, et al. Effect of predefined order sets and usability problems on efficiency of computerized medication ordering. International journal of medical informatics 2010;**79**(10):690-98.

39. Reckmann MH, Westbrook JI, Koh Y, et al. Does computerized provider order entry reduce prescribing errors for hospital inpatients? A systematic review. Journal of the American Medical Informatics Association 2009;**16**(5):613-23.

40. Runciman WB, Hibbert P, Thomson R, et al. Towards an International Classification for Patient Safety: key concepts and terms. International Journal for Quality in Health Care 2009;**21**(1):18-26.

41. Wilson RM, Runciman WB, Gibberd RW, et al. The Quality in Australian Health Care Study. Medical Journal of Australia 1995;**163**(9):458-71.

42. Taylor JA, Loan LA, Kamara J, et al. Medication administration variances before and after implementation of computerized physician order entry in a neonatal intensive care unit. Pediatrics 2008;**121**(1):123-28.

43. Blum KV, Abel SR, Urbanski CJ, et al. Medication error prevention by pharmacists. American Journal of Hospital Pharmacy 1988;**45**(9):1902-03.

44. Leape LL, Cullen DJ, Clapp MD, et al. Pharmacist participation on physician rounds and adverse drug events in the intensive care unit. Journal of the American Medical Association 1999;**282**(3):267-70.

FIGURE LEGEND

Figure 1. Data collection and analysis process. On the left (see A.), the generation of void alerts, follow up interviews with clinicians, and the outcomes are shown (i.e., clinician-reported reasons for voiding (interview), and factors contributing to medication ordering errors). On the right (See B.), the chart review and the outcomes from the chart review process are shown. The study was conducted between January 27, 2016 and July 29, 2016. The frequencies of total inpatient medication orders (age>18), voided medication orders, interviews conducted, and medication ordering errors identified are also provided.

Figure 2. Proportion of reasons for medication ordering errors based on clinician-CPOE-selected reasons, clinician-reported reasons (interview) and based on chart review. Note that the proportions for reasons are based only on those voided orders identified as medication ordering errors after chart review ($n=94$). The set of reasons (x-axis) includes all unique reasons that were identified across the three methods. However, some reasons were appeared only in one method. For example, "discontinuation issues" was identified only in the clinician-reported reasons (interview) method and not the others. Refer to Appendix Table 5 for the proportions and frequency for each reason.

Table 1. Descriptions of core categories and sub-categories related to the "why it happened" theme (core categories were adapted from [21, 29]). CPOE: Computerized Provider Order Entry; EHR: Electronic Health Record.

Core Categories	Associated Sub-Categories	Definition
CPOE Order Entry Issues	Order set/template/protocol issues Repeat Prescriptions and Automated Processes System Interface/Usability/Visual display Missing Drug Component Multiple Orders (Same Clinician)	Issues resulting from breakdowns during the CPOE-based ordering workflow.
User-related Issues	Communication Issues Failure to Follow Procedures/Protocol Inexperienced CPOE User Lack of Clinical Knowledge Multiple Orders (Multiple Clinicians) Repeat Prescriptions and Automated Processes Data Entry Errors Workaround Wrong Dose/Route/Form	Issues resulting from inappropriate work processes followed by the user (clinician).
System Limitations	Drug Formulary Issues Routing/Mapping Issues	Issues resulting from inefficiencies in the use and integration of multiple clinical systems (EHR, pharmacy system, medication administration record).
Transition Issues	Medication Reconciliation	Issues resulting from poor care transitions related to changes in the patient's disposition status.

Table 2. Description of the data sources used for analysis. CPOE: Computerized Provider Order Entry

Data Variables	Definition	Source of Data
Clinician-CPOE-selected reasons for voiding	One of the eight reasons selected by the clinician at the time of voiding	Patient chart documented as the "reason for voiding"
Clinician-reported reasons for voiding (interview)	The reason for voiding as described by the clinician during their interview within 24 hours of voiding	Follow up interview with the clinician
Medication ordering error reason (chart) [used as a gold standard for comparisons]	The reason for medication ordering error as determined based on chart review	Retrospective review of charts of the voided orders with a follow up interview

APPENDIX: SUPPLEMENTARY MATERIAL

SECTION 1. MEDICATION VOIDING

Appendix Figure 1. The process of using the "void" function is shown. The clinician selects a medication ("ceFAZolin"), and the right clicks to get a set of options. Selecting the "void" option

creates a new dialog window with a set of voiding reasons. The clinician has to select one from the list or leave the reason as blank.
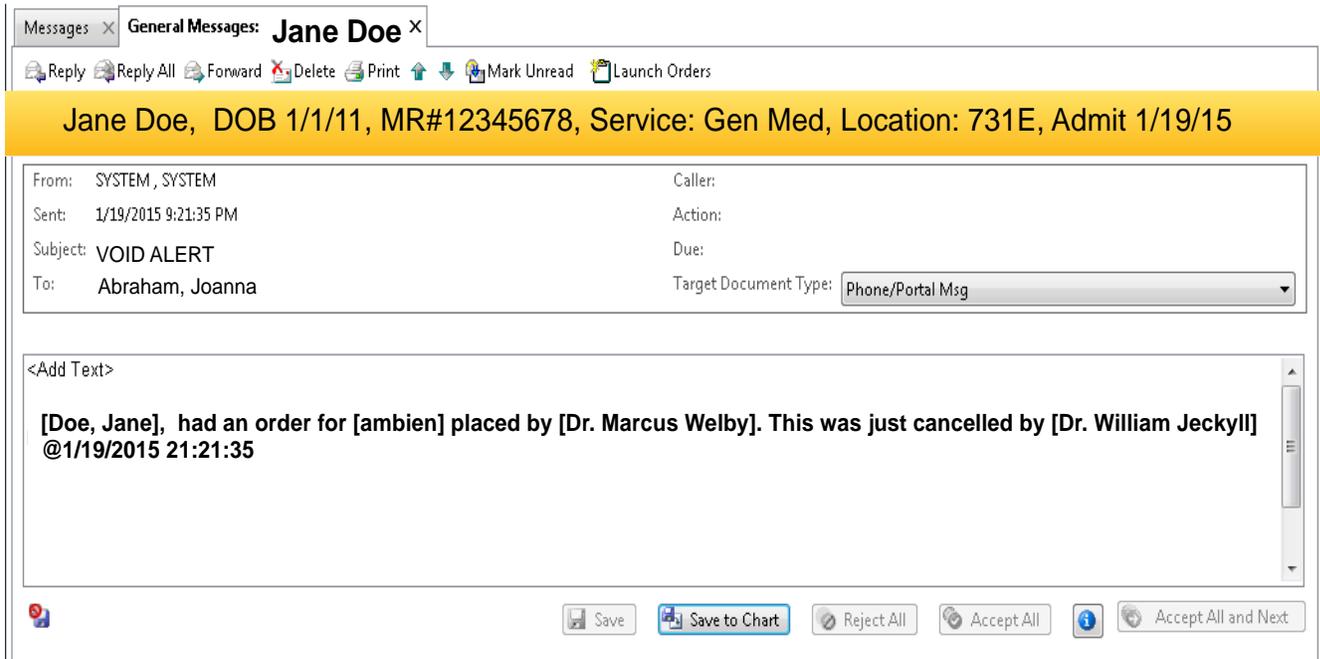
Appendix Figure 2. A screenshot of the void alert secure message that is generated when a medication order is voided. The information includes the patient identifiers, medication information, physician placing the order, and the physician voiding the order. This example image is based on a test patient. Abbreviations: DOB: Date of Birth; Gen Med: General Medicine. MR#: Medical Record Number.

SECTION 2. INTERVIEW QUESTIONS

Interview Guide for <u>Voiding</u> Clinician

1. Why did you choose to void the order for [medication name] on [patient name] in [Bed No.]?

2. How did you identify this order needed to be voided?

3. What factors do you think contributed to this order needing to be voided?

4. Did you discuss the voiding of the order with the ordering clinician, before voiding the order? Why/ Why not?

5. Can you think of any ways to address the issue of [reason of the void]?

Interview Guide for <u>Ordering</u> Clinician

6. Are you aware that your order of [medication name] for [patient name] was voided?

7. Can you explain why the order for [medication name] was placed?

8. Can you confirm that this order should have been voided?

9. Do you know more about why this order was voided?

10. Can you think of any ways to address the issue of [reason for the void]?

Interview Guide for <u>Same Voiding & Ordering</u> Clinician

11. Why did you choose to void the order for [medication name] on [patient name] in [Bed No.]?

12. How did you identify this order needed to be voided?

13. Can you explain why the order for [medication name] was placed?

14. What factors do you think contributed to this order needing to be voided?

15. Can you think of any ways to address the issue of [reason for the void]?

SECTION 3. VOIDED ORDER CHARACTERISTICS

A summary of the roles of the voiding clinicians (see Appendix Table 1), roles of the ordering clinician (see Appendix Table 2), and the clinical location of patient at the time of the order (Table 3) are provided below. In addition, we also provide the basic demographic characteristics of the patients associated with the voided orders. These summary statistics are based on all voided orders that were followed up with interviews (*n*=101).

Appendix Table 3. Counts of the roles of clinicians who voided medication orders in our study (total n=101).

Voiding Clinician	Count
Nurses	22
Physicians	30
Pharmacists	49

Appendix Table 4. Counts of the roles of clinicians who originally ordered the medication that were eventually voided (total n=101).

Ordering Clinician	Count
Nurses	20
Physicians	52
Pharmacists	21
Students	8

Appendix Table 5. Clinical location of the patient at the time of the order (total n=101).

Clinical Location	Count
Medicine	21
Critical Care	19
Surgery	38
Obstetrics	8
Psychiatry	3
Orthopedics	2
Not Known	10

Appendix Table 6. Basic demographic characteristics of patients whose orders were voided (total n=101).

Patient Characteristics*	
Male	*n*=55

	Mean=50
Age	(S.D.=17)

*It must be noted that a prior study found that medication order voiding was associated only with clinician role (physician, pharmacist, nurse, student) and type of medication order (inpatient, prescription, home medications by history), but not with the patient characteristics (Kannampallil et al, 2017).

Appendix Table 7. The proportion of clinician-reported reasons for voiding (interview), clinician-CPOE-selected, and chart review based reasons for those voided orders identified as errors (N=94). The actual frequency of errors is also shown in parenthesis. The proportions were calculated based on the number of orders identified as errors (N=94). Figure 2 in the manuscript is based on the proportions in this table. NA indicates that the reason category was present in that set of reasons.

	Clinician-reported (interview) (n); N=94	Clinician-CPOE-selected (n); N=94	Chart Review (n); N=94
Duplicate Order	0.47 (43)	0.62 (58)	0.47 (44)
Improperly Composed Order	0.40 (38)	0.27 (25)	0.44 (41)
Incorrect Ordering Physician	0.01 (1)	0.01 (1)	NA
Order not processed/delayed	0.01 (1)	NA	NA
Voiding Student Order	0.01 (1)	0.06 (6)	0.02 (2)
Wrong Drug	0.05 (5)	NA	0.03 (3)
Wrong Encounter	0.02 (2)	NA	0.02 (2)
Wrong Patient	0.01 (1)	0.04 (4)	0.01 (1)
Wrong Time Selected	0.01 (1)	NA	0.01 (1)
Discontinuation issues	0.01 (1)	NA	NA

SECTION 4. REASONS FOR MEDICATION ORDERING ERRORS

Appendix Table 8. Reasons for medication ordering errors, the factors contributing to the errors, example snippets from the interview data. The medication ordering errors reasons included were based on those identified from chart reviews (n=94 medication ordering errors). There were seven reasons that were identified (duplicate orders, improperly composed orders, wrong drug, voiding student order, wrong encounter, wrong patient, and wrong time selected). The definitions of each of these error reasons and frequency of each are also included. In addition, the factors contributing to each of these error reasons and their frequencies are also provided with examples from the interview data. For each of the quotations, we have also provided the creator of the order and the voiding clinician.

Reasons for Medication Ordering Errors	Frequency	Example from Interviews
Duplicate Order *Definition*: An identical order to one already active in the list of medications	*44*	
Order Entry Issues	*22 (50%)*	
System Interface/Usability/Visual display	12	Physician: *"When you are putting in the order all it will show you is the order you are putting in, but as soon as you complete it and sign for it, it shows you all of the patient orders, so at that point you could see that there were two aspirins."* [Ordering & Voiding: Physician]
Order Set/Template/Protocol issues	8	Physician: *"I had two orders, and on every single order there was a separate DVT [Deep Vein Thrombosis] alert with the order set and it wouldn't let me order my order that I was trying to enter unless I clicked on the Heparin on both. So, this is a glitch in the system, it's very unhelpful and tedious and slows down ordering everything else. That's why I ended up with 2 heparin orders because I was trying to put in 2 orders for magnesium and potassium."* [Ordering & Voiding: Physician]
Multiple Orders (Same Clinician)	2	Pharmacist: *"The duplicate order [naloxone] was placed using the verbal order given by physician."* [Ordering: Physician; Voiding: Pharmacist]
User-related Issues	*20(45.5%)*	
Multiple Orders (Multiple Clinicians)	14	Pharmacist: *"The other doctor ordered 3 mg of warfarin ... the second doctor never knew that it was already in. so it was a duplicate order...if the original prescriber didn't put the order in the first place then there will be no reason to void."* [Ordering: Physician; Voiding: Pharmacist]
Data Entry Errors	3	Pharmacist: *"The order I entered was incorrect."* [Ordering & Voiding: Pharmacist]
Failure to Follow Procedures/Protocol	1	Nurse: *"There has recently been an effort not to use motrin in patients with a hypertensive disorder."* [Ordering: Nurse; Voiding: Pharmacist

Inexperienced CPOE User	1	Physician: *"Orders had to be placed twice because of an insurance question about medications, and it was unknown how to fix insurance issues in Cerner."* [Ordering & Voiding: Physician]
Communication Issues	1	Pharmacist: *"I just think they were not communicating, the team, so two different residents just put in the same order. It actually happened at a handoff, we get labs back around 4 am in the ICU, and we handoff around 6, and sometimes the overnight person will put in orders, especially with electrolyte replacement, it's then not told to the day person that the order is already placed. That's kind of the first thing we do when we come in in the morning. So, we basically ordered it twice for this patient."* [Ordering: Physician; Voiding: Pharmacist]
System Limitations	*1 (2.2%)*	
Drug Formulary Issues	1	Pharmacist: "*I was trying to enter a non-formulary order, I wanted to change it so it would be put in correctly. This is not a medication that we have in our formulary. The dose ordered does not match anything in our system. It's hard for the prescribing clinician to know what we have exactly in our system. We try in our end to work it out so that it's ordered properly and it matches the drug that we are dispensing.*" [Ordering: Physician; Voiding: Pharmacist]
Transition issues	*1(2.2%)*	
Medication reconciliation	1	Pharmacist: *"I think the patient was supposed to take antibiotics for 10 days, he was supposed to go home before the 10th day of hospitalization, unfortunately he stayed longer, so we sent the prescription in preparation for him to go home, but because he stayed longer, we ended up voiding the prescription because it's no longer needed."* [Ordering & Voiding: Pharmacist]
Improperly Composed Order *Definition*: Any error in the construction of the order: route, dose, schedule, or strength.	**41**	
User-related Issues	*29(70.7%)*	
Data Entry Errors	14	Physician: *"… there is an order for vancomycin for 1.5 ml … which is not an appropriate dose it was 1.5 gram … They ordered 1.5 ml instead of 1.5 gram."* [Ordering: Physician; Voiding: Pharmacist]
Lack of Clinical Knowledge	5	Pharmacist: *"In this case the clinician had ordered a prescription [apixaban] to be broken in half with a pill that should not be broken."*

		[Ordering: Physician; Voiding: Pharmacist]
Inexperienced CPOE User	3	Nurse: *"The order that I placed was for IV [intravenous] fluid with a bolus, except that I didn't want the bolus. So, what I did was copied the previous order fully with the intention of changing the rate, but what happened was that it also copied the bolus and I didn't want the bolus, so I just decided to not copy the original order, which I should have just done in the first place."* [Ordering & Voiding: Nurse]
Wrong Dose/Route/Form	3	Physician: *"It [ciprofloxacin] was ordered in a capsule form and it needed to be liquid because she had a g-tube [gastronomy tube]."* [Ordering & Voiding: Physician]
Communication Issues	1	Physician: *"They [consults] wanted him on a high-dose [of insulin aspart] instead of a low-dose."* [Ordering: Pharmacist; Voiding: Physician]
Failure to Follow Procedures/Protocol	1	Nurse: *"Because the patient is a renal case, we usually use saline instead of LR [lactated ringers]. It's the protocol here that when a patient is on dialysis or renal issues that they're given saline, because of the potassium level in LR."* [Ordering & Voiding: Nurse]
Repeat Prescriptions and Automated Processes	1	Physician: *"I keep one in until I order the other one; it's typically how I order things. I cancel after I put the new one in."* [Pharmacist: Voiding Clinician; Physician: Ordering Clinician]
Workaround	1	Pharmacist: *"The physician entered an order [dextrose for Total Parenteral Nutrition] that was impossible."* [Ordering: Physician; Voiding: Pharmacist]
System Limitations	*8(19.5%)*	
Drug Formulary Issues	5	Pharmacist: *"I voided after I spoke to the nurse because it said that we have the product but they just entered as a non-formulary medication when they should have ordered to the respiratory care pathway so that's why I voided it. So, it was not properly composed order. Because it's not a valid order, they didn't order it correctly therefore I just voided it out."* [Ordering: Physician; Voiding: Pharmacist]
Routing/Mapping Issues	3	Pharmacist: *"Sometimes when they convert their home meds the med record does not match the order system, so we just need to order it the way our system recognizes, basically order doesn't match our order system."* [Ordering: Physician; Voiding: Pharmacist]
Order Entry Issues	*3(7.3%)*	

Missing Drug Component	1	Pharmacist: *"I voided it because it appeared to be a mistake. The 250 NS [Normal Saline] looked like it was part of an order for a phenylephrine or norepinephrine drip. Somehow the drug component got deleted and the order for the NS by itself came through."* [Ordering: Nurse; Voiding: Pharmacist]
Order Set/Template/Protocol issues	1	Pharmacist: *"There are 2 different doses of morphine that were ordered. I think it was an order set, and instead of choosing one or the other, the physician put the order in with both doses of morphine."* [Ordering: Physician; Voiding: Pharmacist]
Repeat Prescriptions and Automated Processes	1	Physician: *"The order was originally placed because scopolamine patch was part of patient's home medication list and I initially thought that she should continue getting it while in house but then I thought better of it because if she came in with c/o nausea and vomiting clearly her home scopolamine patch was ineffective. Therefore, I voided it and ordered ondansetron."* [Ordering & Voiding: Physician]
Transition issues	*1(2.4%)*	
Medication reconciliation	1	Physician: *"The patient was admitted from a nursing facility where his medication list includes both carbamazepine and oxcarbazepine. Our hospital pharmacy was hesitant to fill it as it is unusual for someone to be on both of these antiepileptic medications concomitantly. The order was taken out, pending recommendations from neurology regarding his antiepileptic regimen."* [Ordering & Voiding: Physician]
Wrong Drug *Definition*: An order indicating the wrong medication for the patient (Wrong drug errors may be considered as improperly composed, given that it was a specific medication error, we classified it separately)	***3***	
Order Entry Issues	*2(67%)*	
Order set/template/protocol issues	2	Physician: *"I ordered a dilaudid PCA [Patient Controlled Analgesic] and had changed it to a morphine PCA, but forgot to unclick the remainder of the order set (nalbuphine, ondansetron, and naloxone) while reordering the new medication."* [Ordering: Physician; Voiding: Pharmacist]
User-related Issues	*1(33%)*	

Lack of Clinical Knowledge	1	Physician: *"Pharmacy informed me that heparin was a more appropriate choice for this patient (opposed to enoxaparin which was the original order)."* [Ordering: Physician; Voiding: Pharmacist]
Voiding Student Order *Definition*: Removing an erroneous order created by a medical student.	*2*	
Order Entry Issues	*1 (50%)*	
System Interface/Usability/Visual display	1	Physician: *"I chose to void the order because it was placed by a medical student and we decided to put the patient on different antibiotics."* [Ordering: Medical Student; Voiding: Physician]
User Issues	*1(50%)*	
Lack of Clinical Knowledge	1	Physician: *"I voided the order because the medical student had ordered it thinking the calcium was low and needed to be replaced. First of all, we don't usually replace calcium with calcium gluconate (which is generally used for cardiac stabilization), using calcium carbonate orally instead. Secondly, the student failed to correct the calcium for the low albumin, and it didn't need to be repeated."* [Ordering: Medical Student; Voiding: Physician]
Wrong Encounter *Definition*: An order placed on the incorrect patient encounter episode that causes it to be non-actionable for the intended care of the patient.	*2*	
Order Entry Issues	*1(50%)*	
System Interface/Usability/Visual display	1	Physician: *"It's an interface issue because I had selected an encounter when she was an inpatient, it still was making me order it as an inpatient even though that was an old encounter."* [Ordering & Voiding: Physician]
User Issues	*1(50%)*	
Data Entry Errors	1	Nurse: *"I selected a wrong encounter, I selected an inpatient encounter, and so I realized I put the script in that it was inpatient listed under medication list, so then I voided that; I needed to put in a script that I could e-script to the pharmacy."* [Ordering & Voiding: Nurse]
Wrong Patient *Definition*: An error where the order was placed on a patient who was not the intended patient.	*1*	
User-related Issues	*1(100%)*	

Data Entry Errors	1	Physician: *"I had two patients' tabs open and placed orders on the wrong one."* [Ordering & Voiding: Physician]
Wrong Time Selected *Definition*: An error where the time of administration selected was incorrect.	**1**	
User-related Issues	*1(100%)*	
Data Entry Errors	1	Physician: *"Medical students put in a wrong time and then ordered it on correct time so I co-signed the one which was correct and voided the incorrect one."* [Ordering: Medical Student; Voiding: Physician]

References

Kannampallil, T.G., Abraham, J., Solotskaya, A., Philip, S.G., Lambert, B.L., Schiff, G.D., Wright, A. & Galanter, W.L. (2017). Learning from Errors: Analysis of Medication Order Voiding in CPOE Systems. *Journal of the American Medical Informatics Association*