# CPOE Workarounds, Boundary Objects, and Assemblages

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**ABSTRACT**

We conducted an ethnographically based study at a large teaching hospital to examine clinician workarounds engendered by the adoption of a Computerized Prescribe Order Entry (CPOE) system. Specifically, we investigated how adoption of computerized systems may alter medical practice, order management in particular, as manifested through the working-around behavior developed by doctors and nurses to accommodate the changes in their day-to-day work environment. In this paper, we focus on clinicians' workarounds, including those workarounds that gradually disappeared and those that have become routinized. Further, we extend the CSCW concept of boundary object (to "assemblage") in order to understand the workarounds created with CPOE system use and the changing nature of clinical practices that are increasingly computerized.

**Author Keywords**

Medical orders, electronic patient records, CPOE, EHR, boundary object, assemblage, CSCW, health informatics.

**ACM Classification Keywords**

H.0 [information systems]; K.4.3 [organizational impacts]: Computer-supported cooperative work.

## INTRODUCTION

As defined in previous studies, "workarounds" are "informal temporary practices for handling exceptions to normal workflow" [9, p. 1561] or "work patterns an individual or a group of individuals create to accomplish a crucial work goal within a system of dysfunctional work processes" [14, p. 52]. Workarounds occur when a routine is blocked by certain obstacles intentionally or unintentionally introduced, while the desired task could be reasonably achieved through bypassing the obstacle rather than directly addressing its cause.

Workarounds are particularly pervasive in healthcare settings, which are complex, non-linear environments full of disruptions and exceptions. To accommodate unexpected situations, healthcare professionals are masters at workarounds and oftentimes clinicians view workarounds as the only way to accomplish their work [14].

In healthcare, workarounds have become a more salient issue with the increasing adoption of computerized systems, which introduces radical changes to every single aspect of clinicians' work practices. On one hand, working around inappropriate constraints embedded in a computerized system (e.g., unmindful designs due to software developers' limited understanding of the realities of clinical work) helps improve efficiency and achieve what is otherwise difficult or unachievable. On the other hand, unrestrained practice of workarounds circumventing intentionally enforced blocks (e.g., patient safety assurance measures) may result in adverse consequences detrimental to patient care, creating "an environment that is ripe for failure." [14, p. 52]

To understand the interplay between technology, clinicians' cooperation and coordination, and the competing priorities of accelerating work while complying with recommended practices, we conducted an ethnographically based study at a large teaching hospital where a commercially sold CPOE system was introduced during our field investigation. Briefly speaking, a computerized prescriber order entry (CPOE) system allows clinicians with prescribing privileges to place medical orders (e.g., medications, lab tests) that will then be electronically transmitted to pharmacies, nurses, and procedural units.

Compared with other types of computerized systems popularly used in healthcare, implementation of CPOE has been particularly problematic due in part to the complex nature of inpatient care in contrast with the overly simplistic models underlying current CPOE designs [15]. This makes our field investigation, conducted *before*, *during* and *after* the CPOE implementation, an ideal environment for the exploration of issues related to clinician workarounds. In this paper, we focus on how the CPOE system altered the medical order practices in our study setting, the workarounds doctors and nurses created, and reasons for these workarounds from cooperation, negotiation, and information assembling perspectives.

In the next section, we review the relevant literature. Then, we present our study setting and data collection. Next, we describe several representative cases that illustrate the complexity of medical order practice and the salient workarounds used by doctors and nurses in order


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management. In the Discussion section, we attempt to conceptualize medical orders as boundary objects and the CPOE as an information assemblage to better understand computerized records in medical settings, which provides a lever to understanding clinicians' needs for workarounds. We conclude with implications for improving the design of CPOEs.

## LITERATURE REVIEW

Even though numerous studies have documented clinician workarounds of technological systems, such as working around a barcode medication administration system [11], electronic patient records [24], and computerized medical dispensing system [2], few have examined the issue in detail, and even fewer have been focused on CPOE. As Halbesleben et al. pointed out, despite the obvious gravity of the issue particularly given possible associations with patient safety, the paucity of pertinent research on clinician workarounds of CPOE is "troubling" [7, p. 3].

In addition to enabling electronically prescribing and instant order delivery, most modern CPOE systems also provide decision-support models capable of creating 'blocking conditions' to make the conduct of certain undesirable behaviors 'impossible' (hard-stops) or 'difficult' (soft-stops). For example, as a certification requirement, most of the commercially sold CPOE systems have interaction alerts or dosage checks built in that can prohibit certain actions, or require an explicit acknowledgment from prescribers before certain actions can be committed in the system. The efficacy of such intentional blocks has been demonstrated in the literature; for example proper use of CPOE's alerting functionality has contributed to reduced rates of severe medication errors [3], fewer interaction events [6], and improved physician prescribing behavior (e.g. adherence to recommended drugs and dose) [21].

Nonetheless, it has also been widely acknowledged that not all CPOE blocks have worked as designed [16]. As prior review studies have shown, overriding safety alerts provided in CPOE is very common, occurring in 49% to 96% of cases, which is attributable to reasons such as alert fatigue caused by poor signal-to-noise ratio [22, 26]. Additionally, CPOE adoption is often associated with unintended adverse consequences due in part to inappropriately introduced blocking conditions or levels of sensitivity [10, 15]; for example, rigid patient safety procedures that do not accommodate the need for expedited actions during emergency situations [8].

Hence, workarounds may represent a natural response initiated by clinicians, *for good or ill*, to mitigate the burden of handling restrictions enforced by a CPOE. However, a multiplicity of workarounds also signifies 'chance-taking," used solely to address immediate problems while neglecting or ignoring the impact on subsequent processes or others' work [25]. The double-edged nature of workarounds in CPOE motivated us to use an ethnographically based approach to investigate the nature of clinician workarounds; the manifested end-user adoption and software design issues; and, the underlying conflicts between automation, clinicians' autonomy, and the realities of clinical practice.

To better understand workarounds, we draw on two theoretical concepts from Information Science and Computer Supported Cooperative Work (CSCW). First, medical orders demonstrate many defining characteristics of boundary objects [4, 19]. A boundary object is a shared information object, created mostly by one group (e.g., doctors) and used by other groups (e.g., pharmacists, nurses, and lab/radiology units). Boundary objects lose context as they cross organizational boundaries as they get decontextualized. Research has produced detailed accounts on how these shared information objects are created and used in different organization settings (e.g., [1,12, 13]).

Second, CSCW researchers have argued that it is critical to understanding work in the context of wider cooperative work arrangements [17, 18]. For example, in examining architectural design and planning, Schmidt and Wagner use 'ordering systems' to refer to an *assembly* of "interrelated artifacts, classification schemes, notations, nomenclatures, standard formats, validation procedures, schedules, routing schemes, etc." [18, p. 402]

Building on these studies, to understand the nature of workarounds, we further define the concept of "assemblage" as a complex system that includes *boundary objects*, the *practices* around these objects (including organizational policies), *work processes* and *coordination mechanisms* within these objects, and *special functions* for designated groups. We aim to present how understanding boundary objects and assemblages helps in understanding the workarounds created within a CPOE system.

## ABOUT THE STUDY

The field study setting was an internal medicine unit at a large teaching hospital. A homegrown electronic health records (EHR) system, which we refer to as eCare in this paper, has been deployed and used in the hospital for over a decade. Doctors use eCare to generate patient records, such as admission, progress, and discharge notes. Nurses also document their nursing plan of care in eCare. Other documents, such as a patient's 24-Hour Flowsheet, are still paper-based at the present. During the first four months of our study, medical order management was in paper operation, and then it was replaced by the CPOE. This gave us a unique opportunity to observe the pre- and post-adoption changes in clinicians' order practices. Our field observations continued for another fourteen months after the CPOE implementation, allowing us to see how some of workarounds created by the technology intervention were gradually resolved or became routinized.

Our observation focused on one doctor team in general medicine (including 3 attending doctors and 21 residents working with monthly rotation), in addition to one nursing unit affiliated with the internal medicine department (staffed by 56 nurses). We also interviewed 8 doctors and 15 nurses from other teams or nursing units in order to gain a broader understanding of workarounds related issues that emerged during the CPOE use.

## DATA AND DATA COLLECTION

This report is part of a larger study consisting of field-based observations augmented by the examination of patients' medical records and clinicians' working documents, in addition to semi-structured interviews with clinicians. The first author performed the field observations and other data collection. She shadowed clinicians' day-to-day work, typically from three to five hours in each session. During the CPOE activation period (three days of system converting from paper to electronic system), she spent about 8 hours each day observing the conversion activities (performed by nurses). In addition, she participated in the CPOE training sessions and also three CPOE feedback meetings (after the CPOE adoption), organized by the hospital administration. Her fieldwork consisted of over 750 hours through 18 months.

For the study reported in this paper, we extracted the appropriate portions from observational notes and interview transcripts related to order practices. We focused on information use issues and analyzed these issues from a social/symbolic interactionism perspective [20]. This perspective provided us a "worldview" for interpreting how meaning was created and conveyed through social interactions among different social players, i.e., an interdisciplinary clinician team. As will be discussed below, we found Strauss' emphasis on the constant negotiation of social practices insightful along with his interest in temporal flows of work and information. We also used his student Star's concept of boundary object heavily [19].

In our study, we first identified the workarounds and problematic order management after the CPOE adoption; then, we conducted interviews to further understand the issues from the clinicians' perspectives. Throughout, field notes and interview transcripts were used to corroborate one another during the data analysis process.

## MEDICAL ORDER PRACTICE

Most medical orders are prescribed by doctors. Medication orders need to be verified and dispensed by pharmacists, and then administrated by the nursing staff. Procedural orders are executed by lab/radiology and other procedural departments or by nurses. Dietary and other referral orders go to the meal service and referral arrangement unit. These different clinical groups utilize the orders in distinct ways, but the orders serve as central, shared information objects (i.e., boundary objects [19]) that connect and integrate all clinicians with a unified organizational goal—to improve patients' medical conditions and avoid hospital-acquired complications and medical errors. Before computerization, a handwritten order was carbon copied (see top portion in Figure 1). If it were a medication order, it would be faxed to the pharmacy. Then, pharmacists transcribed the medication order into their own system. If it were a procedural order, the clerk would fill in a requisition form, which would be collected by a procedural unit that then transcribed essential information into their departmental information systems.

For all orders (i.e., medication, lab/radiology, dietary orders, and direct nursing care), nurses always received a second copy in the patient order tray located at the nursing station (see bottom portion in Figure 1). Then, they would transcribe procedural orders (including IV medication orders) into the nursing Kardex.[1] For medication orders, nurses transcribed them into paper-based Medication Administration Records (MAR) that became a part of a patient's permanent record. MARs were used to record medication administration, including the prescription, scheduled time to administrate, actual time to take the action, whether the patient's refused the medication, and other side notes.

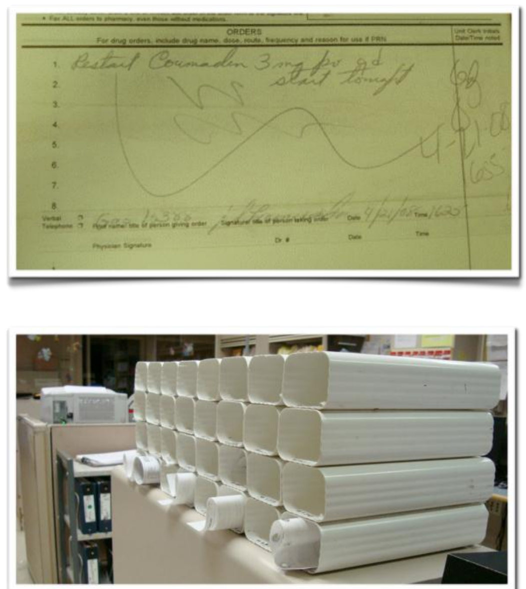

**Figure 1. An example of doctors' handwriting orders (top) and order trays at the station center (bottom)**

This was an error-prone process that involved multiple steps of transcription. Pharmacists, lab/radiology technicians, and nurses' interpretations of the transferred orders could be different from what doctors originally meant, or pharmacists and nurses might have different understanding when they interpreted doctors' handwriting. The cascading handoffs could easily result in omissions and errors; for example, missing orders on the Kardex cards were not uncommon. To reduce errors produced in this process, the computerization of medical orders (such as with the CPOE system) allows doctors to write structured

1 A nursing Kardex was a card that provided a quick overview of essential patient care information, including name, age, marital status, religion, allergies, diagnoses, orders, and so on.

electronic orders so other clinicians do not have to interpret handwriting and can take action based on an original order.

In the rest of this section, we first describe the complexity of medical orders, and then we will discuss several workarounds created by doctors and nurses after adoption.

### Complexity of medical orders

Handling of medical orders in a paper-based operation varies to a considerable degree in terms of how the orders are generated. It is not as simple as just executing an order from doctors. Nurses may also get approval to prescribe certain orders when it is necessary to accomplish the work more efficiently. For example, when a nurse saw a patient had blood in her/his stool, if she wanted to test it she would immediately fill out a lab requisition form and send a stool sample to the lab. As a general medicine unit that often receives more VRE[2] patients who potentially should be on Antibiotic Resistance Precaution, the hospital infection control has approved for this unit that when a patient has a history of VRE, nurses can fill out a lab requisition form and send a culture to the lab to have the patient retested for VRE. However, the CPOE blocks nurses from writing lab orders. It is designed in a way that may fit the majority of units in a general situation, but it does not fit well with the practice of a *specific* unit that requires nurses to be more proactive for infection control. As a result, nurses call doctors to order the lab test, which slows down the work.

Medical orders also have a lot of temporal nuance. The different temporality of orders results from the nature of how different orders are executed. For instance, a patient may need to wear a special boot for a foot inflexion. The medical order needs to make it clear how often the boot is supposed to be on and off (e.g. "wear it for six hours" and then "off for six hours"). In the CPOE, however, as soon as the nurse picks up the boot in the procedural unit, the order will be marked as completed and removed from the active order page. When the nurse returns to the unit, this order can no longer be found. Then, she has to ask the doctor again. Even if the doctor tells the nurse how to use the boot, the next shift nurse will not know the same information because there is no order for the boot in the CPOE. The system design for this type of order takes into consideration equipment management from the perspective of the procedural unit rather than from the nursing perspective, but nurses are the ones who ultimately execute the orders.

Furthermore, medical orders in a paper system can be narrative, and the interpretation of such orders can be very easy and straightforward for human readers. However, to maximize the computational potential of electronically prescribed orders, a CPOE system usually breaks down an order into many discrete segments. For instance, in paper world, for an existing heparin order[3], the doctor may write another order, which says,

"*Don't give [patient] his doses of heparin tonight and tomorrow morning, and then restart it tomorrow afternoon.*"

This is a fairly common order that doctors prescribe if a patient has a scheduled procedure the next day. In the CPOE, it takes two different orders along with free-text comments to finish the task. First, the doctor needs to "discontinue" the heparin medication and add on a stop date. To specify the time of the day, doctors have to add a free-text message in the designed comment box. Then, they need to write a new order with the heparin medication in the future and then again add a free-text message in the comment box if they want the starting time or dose to be specific, which is common in this type of situation.

Further, human interpretation is often needed when multiple orders are prescribed for the same medication with a different dosage or administration method. Again, this is not an issue for doctors and nurses in a paper-based operation because they have a shared understanding that the new order always overwrites the old one. For instance, the doctor might want to increase the dosage for the medication prescribed the day before, or change a dietary order from regular to clear liquid or NPO (nothing per mouth). However, the CPOE is not able to tell the subtle difference between the orders. When an order was still active (based on the time range), the CPOE requires a nurse to execute it even though it was a duplicate order that had been invalidated by newly prescribed ones.

Next, we will illustrate how the complexity of order practice resulted in doctors' and nurses' workarounds.

### Doctors' workarounds

The CPOE system brought with it not only new problems, but also workarounds. Two types of workarounds were particularly prevalent in doctors' order practices immediately after the CPOE implementation. They resulted from the inconveniences of 1) prescribing certain orders that were often very intuitive with natural language but difficult with the structured format prescription required by the CPOE, and 2) the extra workload for new orders that needed to override old orders with the same medication.

In the first scenario, doctors started to rely on the comment box to prescribe certain complicated orders. This comment box was designed to provide additional instructions, warnings, or concerns for prescribed medications and was intended to be read by pharmacists or nurses. Because the box allowed free-text, this convenience fitted well with doctors' order practices inherited from previous paper-based operations.

[2] Vancomycin-Resistant Enterococcus (VRE) is normally not dangerous for healthy people. However, because it cannot be controlled with antibiotics, it may cause life-threatening infections in people with compromised immune systems.

[3] Heparin is typically used to treat and prevent blood clots in the veins, arteries, or lungs.

These workarounds resulted in missing and misplaced orders. In the CPOE design, when a medication is correctly prescribed, this order will be grouped with other medication orders and shows up on the Orders pages and also on the eMAR pages (the electronic version of MAR provided within the CPOE system), which provide nurses with a comprehensive picture of all ongoing medication orders. Medication orders always need to be verified by pharmacists and then executed by nurses. When an order was placed in comment box, pharmacists may spot the message, then they re-prescribe it and place it in the right place. However, it is not guaranteed.

Because the comment box was so popular, many missing orders resulted. The hospital administration had to make a decision, which was to take away this function from the CPOE. Afterwards, doctors improved their practice by following the required format. However, there were still some orders that doctors did not want or did not know how to deal with. For example in the situation of Coumadin order (a blood thinning medication where patients often take different doses on different days), the most intuitive order writing in paper world should be something like, "Monday, Wednesday, Friday, please give *x* doses; Tuesday, Thursday, Saturday, give *y* doses." However, very few doctors know how to translate this narrative order into what a CPOE order requires or were unwilling to construct a complex medication order using the structured data entry format. Therefore, they started to use a "write in" order in the CPOE system, which allows a certain degree of freedom for free-text and was designed for the orders that are not in the predetermined order set[4] in the CPOE system. In this situation, pharmacists had to break the order down into several suborders and enter them into the CPOE on behalf of the doctors.

The similar situation also occurs for other complicated orders. As one doctor described,

*"In the past, I used to get calls from pharmacy and nursing saying 'I can't read what you wrote' (laughing) So, that's gone. Now it's much more, 'I don't understand what you want'. Some of it is structural in that the order, as it comes out, sometimes is very confusing. Dialysis is a good example. They're very hard to understand by anyone. I've looked at them. I don't even understand what I wrote. The order when you fill it out looks okay. But when it comes out as an order it's hard to understand for the nurses."*

The second workaround was that doctors often bypassed the system requirement of discontinuing an existing order before prescribing a new one (i.e. modification of the same medication), assuming that pharmacists and nurses would take care of the issue. As mentioned earlier, this was not an issue in a paper-based operation because the common understanding among different parties was that a new order automatically overrode the old one.

However, the design of the CPOE is not able to handle this common understanding. It requires doctors to do extra work—discontinuing the old before prescribing the new order. Since it was not part of doctors' practice in the paper world, as a result, duplicate orders became a major issue during the first few months of the CPOE adoption. Indeed, one nursing representative angrily shouted out during the CPOE feedback meeting organized by the hospital administration, "*The duplicated orders are killing us!*"

The nursing administration encouraged nurses to "educate" doctors not to write a new order before discontinuing the old one. Still, nurses often had to deal with hundreds of accumulated duplicate orders. The only way to solve the problem was to call doctors and ask them to discontinue the previous orders, because nurses did not have sufficient privileges to modify or discontinue orders in the system. When duplicate orders accumulated and became overdue, the system would present bright red solid bars in the eMAR on that medication, which made nurses feel that they were not doing their work correctly. Then, nurses had to 'bug' doctors over and over to discontinue the duplicated orders.

During our interviews, two doctors admitted that they often forgot to discontinue the old orders unintentionally, or they entered the new orders in a hurry, knowing that nurses would not overdose patients and they could come back to clean up when nurses complained. This situation improved after a few months, but it has not gone away completely.

**Nurses' workarounds**

Before the CPOE system was introduced, nurses received doctors' orders from the order trays (Figure 1). They were located at the nursing station where nurses frequently walked by when they rounded between patient rooms and the medication storage room. With this visual cue, they would immediately know there were new orders *at a glance*. The physical layout of the medical order location provided convenient awareness information for nurses to sense what they needed to do. Oftentimes, when they could not take care of an order immediately, they reviewed it but left it in the order tray (as opposed to moving to other places such as their pockets or the MAR). By doing this, an order's physical presence created a constant awareness that kept them from forgetting to take prescribed actions.

After the CPOE implementation, nurses were required to actively log into a computer terminal to receive and review doctors' orders. When they were engaged with direct patient care activities, they could not always do this frequently, so missing scheduled orders occurred more often during the first few days of the system implementation. To resolve this problem, the nursing unit leadership quickly created another workaround. They assigned a clerical staff member to constantly monitor all patients' new order status and to page nurses when no action or acknowledgement was recorded within the

[4] In this site, preloaded standard order sets provide best practice based on evidence-based medicine. Briefly speaking, an order set is a group of medical orders that is recommended to doctors.

appropriate time frame. This mitigated the issue of missing orders, although it escalated the level of interruptions to the nurses' work. Still, this workaround is so far considered beneficial by the ward's nurses.

Another workaround that appeared among the nurses in the study unit, as well as in other units (based on our interviews) was using paper to double-check medication. Some nurses relied on the medication information they scribbled on their personal sheets rather than on the CPOE to double-check the medication order right before they administered it. However, as a patient safety safeguard, there was a policy that required nurses to double-check medication according to the orders verified by the pharmacists, i.e. the paper MAR before the CPOE or eMAR within the CPOE, even though they might have just checked it 20 seconds ago when they prepared the medication in the medication (storage) room.

During the first several months of the new system, nurses complained fiercely about how slow it was to wake a computer from standby at the bedside. As a result, some nurses still used their personal worksheets for this double-check, which was considered poor practice because the manual copy invited human error and patient safety consequences. However, only a piece of paper could allow this check to be instantaneous.

In fact, for some nurses, this practice was not a new workaround—it was the workaround prior to the CPOE adoption. In the paper operation, nurses were required to bring the MAR folder with them into a patient's room, so they could double-check the medication with the MAR before they gave the medicine to the patient.

However, a number of nurses did not want to bring the MAR folder into a patient's room since it was often very bulky (with a hardcover protection and an accumulation of all medication orders). In addition, moving the MAR folder in and out of a patient's room could spread dangerous bacteria, either from hallway to the patient, or from the patient to other people outside. Because of these concerns, even though it was not encouraged, many nurses still copied medication information from the MAR onto their personal sheets at the beginning of the shift.

With the CPOE in place, computers were installed in all patients' rooms, the medication room (which stores patients' medications), hallways, the conference room, and the nursing station center. Hence, nurses could access medical order information in real-time almost anywhere, which eliminated the need for nurses to copy this information onto their personal sheet.

The nursing administration also tried very hard to convince nurses that computers were indeed not as slow as they felt. Particularly, after the hospital finished the upgrade for all computers in the patients' rooms, the unit leadership invited nurses to take a test to see how long it took for a computer to boot up. While the nurses still felt it took ages for the computer to wake up from standby, the test result showed it was really about 20–30 seconds. After that, nurses were convinced that they should use computers at the bedside more often. The unit leadership considered this behavior evolution as a significant "culture change."

It should be noted that for a few nurses, it took them quite a few months to reach their comfort zone, where they stopped copying medication information onto their personal sheets. Many of them had been doing this for years of their nursing career as a way of knowing what medications each patient was prescribed. This traditional and suboptimal practice was, however, gradually replaced by the ease of real-time access to medication information stored in the CPOE at almost any location in the nursing ward.

Another workaround was reported by the nurse supervisor, but apparently used by only a small number of nurses. It involved how nurses handled controlled substances. The CPOE in this hospital can automatically integrate data from an Omnicell, a machine that stores controlled substances and records who accesses them. There are very strict rules about controlled substances. For instance, when a patient refuses a controlled substance that has been already taken out of the Omnicell, the nurse must crush it with a tool, dispose of it in front of a witness, and then record this action. Because some patients may also try to hide the controlled substance for future use, or combine two or more doses to use at one time, nurses always have to pay extra attention to administering pain medication. Accordingly, the supervisor closely monitors all activities related to controlled substances. Below is how she explained her use of the CPOE from an administrative perspective:

*"I do look for that in relation to the narcotic administration from Omnicell. For example, if they (nurses) charted their narcotic at the same time or a couple of minutes before it was taken out of the time recorded in Omnicell I'm pretty sure they charted it in the med room and not at the bedside. Or if they took the medication out of the Omnicell at one time and then they didn't chart the med for two hours that means they probably carried it around in their pocket - is that malpractice which they should not be doing?"*

As discussed earlier, charting the results for medication administration (time and whether the patient took the medication) should always take place *after* the nurse actually finishes at the bedside. When a nurse prepares the medication in the medication room, she needs to get on the CPOE to use the eMAR to check which medication should be pulled out from the boxes or Omnicell for her patient. Since some patients' rooms are just 10 to 20 feet away from the medication room, and the medication will be administrated soon after, some nurses broke the rule by charting the results in the meds room *before* the actual medication administration took place in the patient's room. By doing this, they avoided logging onto the CPOE system again with only a few seconds in between the two locations.

As the supervisor commented, this is considered malpractice. Since nurses are the last defense against medication errors, they need to *"check, check, and check"* whenever there is a status change (e.g. location, time). Opening up a computer at a patient's bedside to ensure the correct medication *right before* they put the medicine into a patient's mouth or inject it is perhaps the last opportunity to prevent a mistake from happening. However, this workaround was, in fact, difficult to detect unless one went through to analyze the timestamps for each nurse and compared the timestamps with the Omnicell data.

## DISCUSSION

The workarounds reported in this paper paint a rich picture of how the work is negotiated and renegotiated in medical order practice through the interactions between doctors and pharmacists, doctors and nurses, nurses and clerks, nursing supervisor and nurses, and so on. In particular, we described how doctors renegotiated their work with pharmacists to prescribe certain complex medication orders, how doctors renegotiated their work with nurses to cope with duplicated orders, and how nursing supervisors interacted with nurses and clerks to improve the work by adhering to best-known practice. Additionally, we depicted various temporal flows within order management that necessitated close cooperation among different stakeholders. Indeed, our understanding of medical work has a prominent focus on negotiation, negotiated order, and temporal flows, all rooted in Strauss' work from a social/symbolic interactionism perspective [20].

In this section, we first reflect on several concerns of the identified workarounds from the system design, work redistribution, and organizational best practice enforcement perspectives. Then, we discuss how the workarounds created around order management can be *better* understood by using the theoretical concept of "boundary object." Lastly, we attempt to develop the concept of "assemblage" to help understand a complex system, including not only shared information objects (medical orders in this context), but also the *practices* around these objects, *work processes* and *coordination mechanisms* embedded within these objects, and the *special functions* for designated groups. Through this study, we hope to illustrate how the knowledge of boundary objects and assemblages may offer insights into understanding the workarounds that clinicians created in their use of a CPOE system.

### System design, work redistribution, and organizational learning

Our first concern is regarding certain workarounds that were indeed introduced by software design. Structured data entry, which is often cumbersome, requires doctors to think and act in counter-intuitive ways, i.e., the documentation process is no longer about clinical reasoning, rather, it has become a mechanical duty of keying in data. Generating this type of mechanical order not only increases doctors' work but also creates extra cognitive workload for nurses when they receive the new orders. It essentially breaks down a fluid human sense-making process into several fragmented information-receiving stages and then requires putting them back together to understand what the doctors really mean. This is at least part of the reason that nurses say that they are now receiving "more prompts" to remind them of new orders coming in or of overdue existing orders.

Second, while the legibility of electronic orders has successfully resolved the problems originating from interpreting doctors' handwriting, the rigidity of the CPOE orders (not allowing discretion, nuance, and interpretation) has changed work arrangements around certain orders. This rigidity has also made clinicians do extra work. Indeed, to maintain the integrity of the order system, the extra workload is distributed to all parties. Nurses and lab technicians have to identify duplicated and unfulfilled orders, which can be many; then, they call doctors to clean them up if the doctors forget to do so. As well, some work arrangements have changed: there is a loss of power for the nurses—they are no longer allowed to prescribe certain lab orders. In this case, the nurses' power loss meant doctors' increased responsibility [29], which slowed down their work, perhaps jeopardizing patient safety (e.g., in the form of delayed tests for harmful bacteria).

In another case, pharmacists were "forced" to assume the responsibility of handling doctors' "write-in" orders (i.e., orders placed using the free-text box that was designed for additional instructions or only for the orders that could not be found in the predetermined order sets). While this imperfect solution has now been accepted as a routine for certain complicated orders, it remains unclear who is officially liable for potential adverse medication events that may be engendered by such workarounds.

Third, the nursing problems identified have been largely corrected with nursing administration's efforts and nurses' improved performance. The unit leadership worked very hard to improve the nurses' practice. As we have seen, they organized nurses to test how fast the computers could wake up from standby and convinced nurses to use the eMAR to double check medication rather than their personal sheets. This led to a positive outcome. Many nurses, including those who originally deeply doubted the system, expressed similar statements to one nurse's description, "*I did not like it [CPOE], now I love it*."

One workaround, assigning a clerk to monitor new orders for nurses, increased awareness to compensate where the CPOE is lacking. While it was an improvisationally-created workaround, it eventually became an accepted practice and an institutionalized new pattern of work throughout the entire hospital. Such process changes can be a critical vehicle to enable organizations to adapt to changing environments through organizational learning [5].

### Medical orders as boundary objects

While the focus of our investigation is on workarounds that have become particularly salient following the introduction of new technologies, this paper is not aimed at enumerating all possible types of workarounds. Rather, we selected a special kind to examine closely—those that were created around shared information objects (medical orders in this context)[5]. These shared information objects are perfect examples of boundary objects. Therefore, applying the concept of boundary objects is particularly pertinent which also enables the analysis of the root cause of the workarounds from a new and unique angle.

Indeed, medical orders are clearly boundary objects that different communities of practice use differently [4, 19]. We have illustrated how different communities use Orders and eMAR when an order or the result of a finished order crosses a boundary: Its status changes (from prescribed, to verified, to executed), and the obligation and responsibility also transition from one group to the other(s).

As boundary objects, medical orders have defined a standard form (i.e. what order needs to be prescribed by whom in what format). This is true in both paper orders and electronic analogs. However, as described earlier, many orders in paper operation can be prescribed with narrative free-text, often a couple of short lines, which convey multiple meanings. In electronic context, each order often has to break down into several entries, which increases doctors' workload and complexity of prescribing practice. Doctors' workarounds, such as asking pharmacists to do their work and ignoring the duplicate order issues, represent non-standard practices and uses of boundary objects.

Prior research in other organizational settings has suggested that tensions and negotiation often occur between the formal and informal use of boundary objects (e.g. [13]). At first glance, the workarounds in our study appear to merely present a new version of this – what was traditional order practice in a paper-based operation is performed in new computerized boundary objects within the CPOE system. The order itself and then the negotiation about its use both fit into the standard boundary object story.

Prescribing within the CPOE requires doctors to construct a structured order. Although they complained about counter-intuitive design, they adapted their behavior with regard to relatively simple orders. For complicated orders, they worked around the system by sending a "write-in" order or using the comment box. This workaround behavior resulted from their old order practice in the paper world (with the protocols embedded in the old boundary object use). For the doctors, when the previous boundary objects (i.e., their orders) were computerized, their practice, based on those boundary objects, then required a significant change from what it had been in the paper world. Workarounds were, then, created against this change.

Similar tension occurred when doctors needed to change the dosage or usage for an order—they previously wrote a new order without having to discontinue the old one. This practice was built upon the common understanding with both pharmacists and nurses: new orders overwrite the old ones. For their work convenience, doctors worked around the system by bringing back their old, paper-based practice against the new requirement imposed by the computerized counterpart. As well documented in other organizational studies, the use of boundary objects often needs negotiation among different communities [13]. The workarounds created by the doctors' use of new boundary objects within new computerized context resulted in further *renegotiation* on the work arrangements with pharmacists and nurses to maintain the integrity of the system.

**CPOE as an information assemblage**

As illustrated above, the concept of boundary objects helps us understand the root cause of important workarounds created by doctors. However, we found this concept alone is insufficient to explain other types of workarounds, such as the workarounds created by nurses when they violate charting results before medication administration, skip double-checking or use their personal sheets to double-check medications, or when a clerk was assigned to monitor new order arrival. Therefore, we found that we had to use a broader concept, assemblage, including not only the information objects, but also the practices (embedding organizational policy), automated work processes, and coordination mechanisms within these objects, to better understand the workarounds created around CPOE use.

In addition to computerizing medical orders and MAR, the CPOE automated both doctors' and nurses' work processes in their order practice by providing predetermined order sets based on evidence-based medicine, allowing nurses to receive their orders instantly from the CPOE as compared to the order tray previously (which helps them assemble patient medication information more efficiently [28]), and recording the medication administration results via eMAR. Because of these automated work processes, the CPOE needed to provide efficient coordination mechanisms to ensure that different groups interacted and coordinated through the status changes of boundary objects (Orders and eMAR). This was realized with various alerts, logos, and color-coding within the CPOE to indicate order status changes. Furthermore, the CPOE has the functionality to allow charge nurses and nursing supervisors to monitor how medications are administered unit-wide. The system also offers several specific functions to aggregate nurses' performance data, particularly how they handle controlled substances. These functions provide managerial control.

These characteristics of the CPOE as assemblage help us understand the workarounds in a much broader context. First, automated processes are a double-edged sword and help create workarounds. For example, the convenience of electronically sending a narrative message (either with a "write-in" or the comment box) to multiple groups, along with the difficulty of prescribing orders while complying with the required structured format, contribute to non-standardized uses of the boundary objects.

[5] Other types of workarounds, such as avoiding documenting certain nursing care information in the designated area of the CPOE, have been reported in one of our earlier studies [27].

Second, from the perspective of nurses, assigning a clerical staff person to monitor new order arrival and page nurses was a good workaround so as to complement the insufficient coordination mechanisms of the CPOE. This was both an easy way to solve the problem and a reasonable work re-arrangement (because of the significant reduction of workload to clerical staff after the CPOE).

Third, in the situation that some nurses still recorded the results of medication administration before seeing patients, or that some nurses still double-checked the medication with their personal papers rather than the eMAR, the CPOE could be used to force compliance with organizational policy and best practice enforcement.

To summarize, the issues related to workarounds discovered from our analysis of medical order practice, through the theoretical viewpoint of boundary objects and the conceptualization of the CPOE as an assemblage, have broad implications for HCI/CSCW, medical informatics, and information science. HCI/CSCW has pointed out that as a research field we should not restrict ourselves to just studying the cases of "group" work where performing a task is assumed to take place in a relatively closed and fixed environment [17]. Groups in a complex organization have to work cooperatively in a much wider arrangement [18]. However, what we have shown here through the lens of workarounds and order practice is that understanding information objects as assemblages which embed multiple shared boundary objects used by different communities and which enable automated work processes and coordination mechanisms, can bring greater clarity to why the workarounds have come to exist.

## DESIGN IMPLICATIONS

The results of this study may suggest several useful design implications. As we have shown in early analyses, some workarounds were *transitory*: they disappeared overtime with continuous training, software upgrades, and redesigned use policies. Others persisted and might eventually become part of clinicians' practice routines. In this section, we focus on the latter type, which are more difficult to address and may reflect fundamental conflicts between medical practice and the design philosophy of healthcare systems. In particular, knowing that certain workarounds might persist for an extended time period and accommodating them partially while introducing safeguarding mechanisms to minimize their potential detrimental effects could yield better results. For example, a system might provide proactive advisories when aberrant actions are detected, to instruct users what the best practices are, which could help correct workaround behaviors gradually.

A prominent observation from the study was that the workarounds initiated by doctors were primarily used to accommodate the complexity of entering orders electronically, a significant conflict rooted in the "incapability" between doctors' thought processes and the structured nature of data entry required by computerized systems (so that the data acquired can be computed for reporting, decision-support, and other secondary use purposes). Documenting via a structured format forces doctors to decompose a coherent medical decision into discrete segments represented by machine-recognizable codes and numbers. Hence, it had been perceived as time-consuming, counter-institutive, and in effect dehumanizing the practice of medicine [23].

The conflict between structured data entry and free-text narratives has been an enduring challenge to introducing computerized systems into healthcare, partially because end users who are responsible for data entry are not the immediate beneficiaries of structured and codified data. This provides general implications into the design of technologies supporting group work, in that workload and benefits should be properly distributed among all affected parties. As we have shown in the study, renegotiation became a central activity in ordering processes, and doctors' reluctance to adhere to recommended practice resulted in many undesirable chain reactions, such as the workload shifting to nurses and pharmacists as well as time wasted in unnecessary communication and clarification. Therefore, a power structure that is unevenly distributed among different clinician types could be a critical consideration in designing systems that can succeed and be sustained in healthcare settings.

Further, while great amounts of investments have been made in building into modern CPOE systems comprehensive decision-support functionalities for preventing medication errors (e.g., overdose, drug-drug interactions), less attention has been paid to preventing problematic prescribing practices, for example, duplicated orders. In the CPOE system used at our field study site, revising an existing order was extremely difficult, requiring multiple steps and redundant data entries (discontinuing currently active orders and then reentering them anew with modified parameters). This issue could be easily mitigated by providing a "revising" function that allows prescribers to carry over unchanged data and automatically discontinue an existing order when a new one is placed.

Additionally, current CPOE designs do not seem to adequately consider multidisciplinary coordination: they do not accommodate well the dependencies of tasks rendered by different types of clinicians. The duplicated order issue, for example, does not manifest at the doctors' end or the pharmacists' end, while its effect cascades to affect nursing work in significant ways. We argue that in designing computerized systems for healthcare, it is critical to inspect the full circle of delivery of patient care rather than separately performed services, given the highly cooperative nature of medical practice.

## CONCLUSION

In this paper, we use CPOE workarounds as a lens to examine the general medical order practice. We found workarounds issues from doctors and nurses' practice.

Some of these workarounds discovered gradually disappeared while some others have become routinized. In this paper, we focused on the latter type which represents both challenges—undesirable workarounds threatening patient safety, as well as opportunities—“smart” workarounds informing new and potentially better ways of incorporating computerized system in clinicians’ job routines. Further, we analyzed doctors’ workarounds as the outcome of employing previous practice to non-standard use of new computerized boundary objects. We extended the concept of “boundary object” to “assemblage” in order to understand the workarounds created with the use of CPOE and with the changing nature of clinical practices that are increasingly computerized.

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