COMPUTERIZED PHYSICIAN ORDER ENTRY SYSTEMS: THE PROMISE OF SAFER, BETTER CARE

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At 6:30 am, Dr. Octavia Warner is off to the hospital. She was notified of two new admissions to her service overnight, and she wants to get an early start because the resident she spoke to sounded tired and did not have as much information as she wanted. There was a low potassium value that she hopes the intern corrected, but she wants to check for herself. July is a trying time due to all the inexperienced interns. She anticipates a long day.

Dr. Warner grabs a bran muffin and coffee on her way to the wards so she can read the charts for the new admissions while she eats. Unfortunately, she is too early and the nurses are giving report. She interrupts one of the nurses and learns that the charts are in another room. Finally locating the chart for the patient with low potassium, she reviews the orders. The paper copy of the low potassium value has not made it to the chart, but she is relieved to see a replacement order was entered appropriately. She searches for other details in the chart, but being a new admission, it is mostly a set of empty binders.

As she turns to replace the chart in the rack, Dr. Warner notices the red "orders pending" flag still on the chart. A surge of anger rises as she condemns the combined ignorance of the house staff and nursing staff for this error. A nurse approaches, interrupting her thoughts, and reports a patient's allergic reaction to a drug ordered last night by one of the new interns. The nurse continues, "... and the patient said he told you last year about this allergy..." Dr. Warner sighs and wonders, "why have hospitals always been like this?"

In another town, Dr. Homer Barnett glances at his PDA before he leaves home and heads to the hospital. His PDA has updated his census of patients over a low-speed secure wireless connection to the hospital network. He had two new patients admitted overnight. An icon appears, showing new laboratory results for the patients. Glancing at one marked critical, Dr. Barnett is momentarily alarmed by a very low potassium. He checks the new orders entered by the house staff and is relieved to see appropriate orders to remedy the situation. Checking the Medication Administration Record, he sees the stat replacement was given surprisingly quickly.

Once at the hospital, Dr. Barnett is inside the high-speed secure wireless network, and his tablet computer automatically logs him in because it can sense that the radio-frequency badge he is wearing is adjacent to the tablet. He stops in the cafeteria to review orders written last night. Being July, he is wary of new graduates taking care of his patients. However, he has noticed that since all medicine units are now live on the computerized order entry system he has not had the same frantic anxiety associated with previous Julys. The system offers inexperienced interns a lot of help as they enter orders. They have all the latest manuals, textbooks, and national guidelines on their computers.

Reviewing last night's orders, Dr. Barnett discovers that a new intern wrote an order for generic ciprofloxacin for pseudomonal urinary tract infection. He smiles, remembering long talks with interns about formularies and cost-effective antibiotic selection. Since the order entry system is checking antibiotic selection and critiquing drug choices, the house staff are writing more sophisticated orders for infections, not necessarily the more expensive choices.

Leaving the cafeteria, Dr. Barnett recalls a conversation he had with an intern last evening. The intern remarked that he was planning to give meperidine for pain to a patient on phenelzine, but the order entry software indicated a contraindication. Dr. Barnett is reminded of the widely publicized Libby Zion case, in which these drugs were prescribed together with a fatal outcome. He shudders to think what might have happened if his hospital did not have an electronic order entry system with drug interaction software.

These two very different physician scenarios characterize a dramatic shift in health care delivery that is on the horizon. While Dr. Barnett's world may seem futuristic, it is not far from what physicians working in a few hospitals, particularly academic health facilities, are already experiencing today. A small

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but growing number of hospitals have implemented system-wide information technology that supports clinical care, vastly improving the operating environment for physicians. Meanwhile, most physicians exist in a world much more like Dr. Warner's, with significant barriers to effective care delivery. However, society is increasingly unwilling to accept current failings of the health care system when proven methods exist to help correct them. In time, information technology *will* change the way we practice. To what extent we welcome this change depends on whether we are skilled in the use of these tools and trust them to aid our efforts to provide quality care to our patients.

In the time since the Institute of Medicine (IOM) published reports on the high rate of medical errors [1] and pervasive quality problems [2] plaguing the U.S. health care system, significant attention has focused on the use of information tools to reduce medical error and improve care delivery. Growing concern about weaknesses of the health care system has led the IOM and other panels of experts to recommend the establishment of a national health information infrastructure [2–4]. As a result, a National Coordinator for Health Information Technology was appointed by the federal government in May 2004 and charged with developing and overseeing a plan to guide nationwide adoption of health information technology in the private and public sectors. The first report by the National Coordinator, issued in July 2004, outlined a vision for "consumer-centric and information-rich care" and a framework for achieving this vision in the next decade [5]. This vision includes the ability of physicians to order tests and treatments using computerized systems that facilitate safe, appropriate, timely, and efficient delivery of these interventions.

It is not surprising that physician ordering is a focus of attention. The quality of care delivered to a patient is directly related to specific orders for diagnostic and treatment interventions—or the lack thereof. By ensuring that physicians have complete and accurate information needed to make optimal ordering decisions, these information tools have the potential to ensure better quality of care. Interest in the use of computerized physician order entry (CPOE) and other innovations in health information technology is on the rise because these tools show promise in helping to address many of the problems identified in recent IOM reports.

Pressure to improve health care safety and quality through the use of CPOE systems is already being exerted by health care purchasers, in particular the Leapfrog Group, a coalition of 150 public and private health care organizations providing coverage to 34 million Americans. A primary goal of the Leapfrog Group is to mobilize employer purchasing power to promote the adoption of proven hospital quality and safety practices. One of these practices is CPOE [6]. The federal government also has established incentives to promote the use of information tools. Although not specifically focused on CPOE, the Centers for Medicare and Medicaid Services recently established a pay-for-performance program to encourage physicians to use health information technology to improve the quality of care for their patients with chronic illness (available at www.cms.hhs.gov/media/press/release.asp?Counter=967; accessed 13 Oct 2004).

Physicians entering the workforce over the next several years can expect a time of turbulence as hospitals, health systems, and community-based practices grapple with the challenge to transition to delivering care that is information-rich. Unfortunately, many physicians in training or new to practice are unprepared to integrate information technology optimally into patient care. Without experience in the use of effective CPOE systems, physicians may be unaware of the potential value this technology offers for addressing current quality problems within hospital medicine and blind to factors that are critical to successful integration of CPOE. The purpose of this article is to provide those who are unfamiliar with CPOE with a conceptual understanding of the functional components and capabilities of well-designed and integrated hospital CPOE systems. A brief review of the literature on demonstrated value of CPOE is provided, followed by a discussion of factors critical to successful implementation of a CPOE system that will offer real value to physicians and their patients.

How Do CPOE Systems Work?

CPOE refers to any computer-based system that allows a physician to enter medical orders directly into a computer rather than writing them on an order sheet or prescription pad, thus ensuring standardized, legible, and complete orders. CPOE systems vary widely in their functional components and capabilities, depending on how the system has been designed and integrated into the hospital information system (HIS) and what software applications and information resources populate the CPOE system.

Order Selection and Specification

One of the most important functions of CPOE is order selection and specification. In a paper-based ordering system, most orders are written one-by-one in an order book or a patient chart without a preprinted order set (order sets do exist for some conditions or procedures). Once an order is written, many people are involved with interpreting and carrying out the order. For example, a registered nurse or pharmacist typically handles medication orders; for other orders, a ward clerk interprets physician intent by translating the written order into an “order-able” service. Results of laboratory or radiologic tests or medications administered must then be noted in paper form and returned to the patient’s chart. The paper-based method of order processing can waste valuable time and increases the possibility of errors. For example, for a drug order, if the physician forgets to specify a dosage form, route of administration, dose, frequency, or duration, he or she will get a call from the nurse or pharmacist for completion of the order.

Instead of facing a blank order form, users of CPOE systems can follow a standard step-by-step process to select and specify orders. To select an order, most CPOE systems support searching or choosing from a menu. A system should allow order selection based on synonyms, so common names can be connected to the sometimes arcane nomenclature of HIS order systems. With CPOE, once the order is selected, the components of the order can be prompted so it is easy to enter the orders correctly. For example, for admission orders, students often learn a mnemonic, such as ADVANDIM (Admit service, Diagnosis, Vital signs, Activities, Nutrition, Diagnostics, IVs, Medications), to remember all critical aspects of admission orders. These steps can be embedded in the CPOE system to ensure that every patient admission includes all relevant information. Some electronic orders can even be completely preconfigured. For example, an order for “acetaminophen 500 mg × 2 by mouth every 4 hours for headache” can be completed in a single click. This saves time during order entry and later in avoided call-backs for common medications prescribed on an as-needed basis. Another advantage of direct physician order entry is the avoidance of errors that may occur if a ward clerk misinterprets a physician’s intent or cannot read an illegible handwritten order. CPOE also completely removes error-prone abbreviations from orders [7].

Preprinted order sets and protocols are standard tools used in hospitals for specific diagnoses or procedures. With a CPOE system, order sets can be translated into the system and additional features can be added. For example, each computerized order set can link to evidence and can automatically generate reports on physician use of the order set. Updating an order set and keeping only the current version in circulation are issues that automatically resolve with computerized management of the process.

Finally, when CPOE systems are integrated with electronic medical record systems, physicians have access to relevant patient information (eg, demographic data, past visits, current medications, problem lists, test results) at the time an order is entered.

Clinical Decision Support

CPOE is not simply for facilitating orders. Most CPOE systems are equipped with some level of clinical decision support, meaning they provide computerized information helpful to physicians while clinical judgments are being made. Clinical decision support works by putting a mechanism in place in the normal clinical workflow to help physicians do the right thing at the right time, so they do not need to expend any additional effort to comply with standards of care they already accept.

Positive clinical decision support. *Positive clinical decision support* refers to the provision of relevant recommendations or information aimed at guiding or improving care decisions, which are based on the current order being specified. Examples include: 1) automatic display of relevant patient data (eg, recent laboratory values that should inform drug dosing) and other information (eg, available dosage forms for medications); 2) templates that guide clinical decision making, with allowable choices and defaults (eg, evidence-based recommendations for cost-effective treatment of pseudomonal infection); 3) predefined orders that can be selected or are automatically displayed when a related order is specified (eg, order to measure serum creatinine prior to performing a computed tomography [CT] scan with contrast); and 4) dose calculators to help with complex dosing orders (eg, offering a corrected gentamicin dose for a patient with impaired renal function). Another example of positive clinical decision support is a recommendation to perform preventive interventions that are appropriate for a patient as per accepted clinical guidelines (eg, pneumococcal vaccination upon discharge for a 66-year-old diabetic patient hospitalized for a foot infection, for whom there is no record of prior vaccination in the patient’s electronic medical record).

Negative clinical decision support. *Negative clinical decision support* refers to a suggestion to stop the current order because it may cause an unsafe condition. An example of negative clinical decision support is checking a drug order against all existing

Table 1. Principles of Effective Decision Support

Physicians will not value a system that slows them down. Speed is critical to success. The speed at which an information system operates is a primary determinant of user satisfaction.

Anticipate physician needs for information at the point of care. Information must be readily available for physicians to use when they want and need to use it. Decision support systems can serve as "information gatherers" and make associations between pieces of information that busy physicians may miss.

A system must understand and anticipate physician workflow. To be useful and used, prompts, guidelines, and other supporting information must fit into a physician's practice pattern (eg, providing guideline information about a drug when the physician is ordering it).

Usability matters. Ease of use can make the difference between success and failure of a decision support system. System developers must make it easy for physicians to practice effectively and efficiently.

Provide alternatives or face resistance. Physicians resist suggestions not to carry out an action (eg, order a nonformulary medication or a redundant test) when alternatives are not offered.

Encourage physicians to modify, not cancel, an order. A decision support system is a powerful tool for changing physician behaviors. Modifying an aspect of care on the system that a physician does not have strong feelings about (eg, dose, duration, or frequency of a drug) can control costs.

Simplify key evidence on screen. Provide key evidence that is condensed and simplified for use at the time care decisions are being made.

Only ask for additional information when it's really needed. Decision support systems occasionally must prompt physicians to provide key data regarding patient care; however, the likelihood of success is inversely dependent on the number of data elements requested. Only request additional data when it is absolutely necessary and cannot be obtained any other way.

Monitor impact, get feedback, and respond. To achieve the desired outcomes of CPOE initiatives, it is essential to monitor and evaluate the effectiveness of alerts and reminders and to make changes to the system if the desired result is not being achieved.

Manage and maintain. Maintaining the system's knowledge and managing the individual pieces of the system are critical steps to successful delivery of decision support.

Adapted from Bates DW, Kuperman GJ, Wang S, et al. Ten commandments of effective clinical decision support: making the practice of evidence-based medicine a reality. J Am Med Inform Assoc 2003;10:523–30 with permission from the American Medical Informatics Association.

drugs that the patient is taking and alerting the physician of potential drug interactions. Using a CPOE system with drug interaction software, Dr. Barnett's intern averted a repeat of the most famous example of drug interaction between phenelzine and meperidine, which resulted in the avoidable death of Libby Zion [8]. This error was attributed to physician fatigue, as the house officer who administered the two drugs had been up all night and failed to notice the potential for a dangerous drug interaction. Although subject to the usual information system perils such as power outages and system freezes, CPOE systems do not suffer from fatigue, memory loss, or uneven performance as their human masters do. Similarly, while it is difficult for busy physicians to remember to check for drug allergy every time a drug is ordered, 100% compliance is typical when using a CPOE system with allergy-checking software. The software can even be programmed to prompt a physician to ask the patient about allergies in the normal course of care.

Other forms of decision support. Beyond prescriptive positive or negative clinical decision support, CPOE systems can be designed to offer additional information that may be helpful at the time an order is entered. A system may provide information to supplement built-in guidance or it may direct users to the original evidence that informs the online advice. A CPOE system also may be designed to suggest hospital policies. For example, hospital restraint policy is frequently complex and difficult to memorize. A link on the order screen can help ordering physicians understand when restraints are to be used and when they are to be avoided.

Principles of effective decision support. In a recent report by Bates et al [9], the authors shared lessons learned from their experience implementing and studying the impact of computerized clinical decision support at the Brigham and Women's Hospital in Boston. Based on what they found does and does not work, the authors identified 10 principles for effective clinical decision support (**Table 1**). Many of the authors' findings will ring true with others who have attempted to implement clinical decision support into the information system at their hospital. For example, the authors found that speed of processing was critical to success. At the University of Wisconsin, we wanted to support prescribers by presenting several recent laboratory results. Although the users liked this feature, it slowed the system measurably because the computer had to make a separate query to the database to retrieve the laboratory results. When we removed the processing that

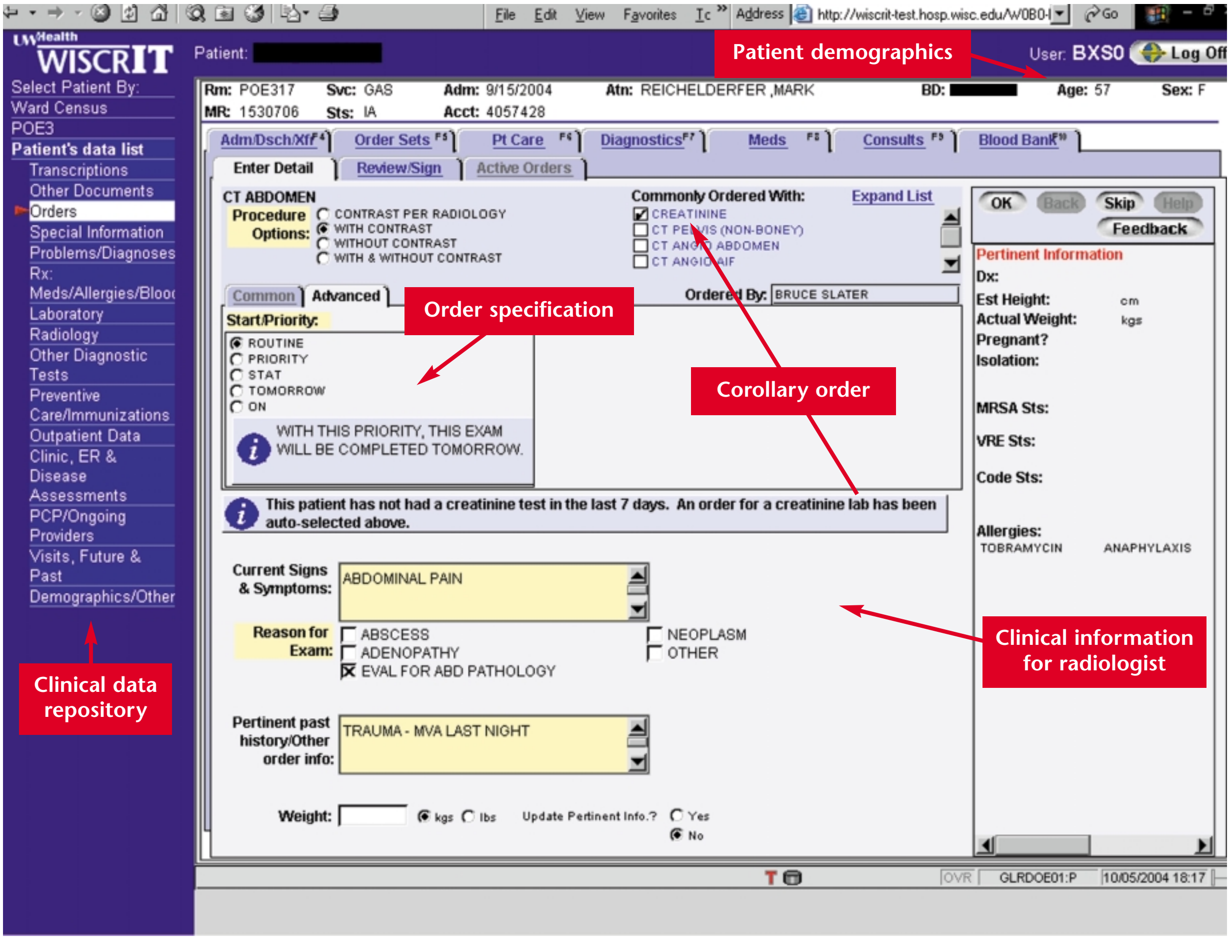

Figure 1. Example of a corollary order prompt. As an order is entered for a computed tomography scan with contrast, the electronic order entry form prompts the user to enter important clinical information for the radiologist who will read the study. In this example, the computer prompts a corollary order for creatinine measurement, because a creatinine result was not available in the clinical data repository. Patient demographics are shown. Order specification is also accomplished on this same page.

supplied the laboratory data, we found that users valued the higher speed more than the ability to view past laboratory results. Whenever possible, clinical decision support should not slow down the user.

An important design principle identified by Bates et al [9] is to anticipate the physician's needs for patient information and to deliver that information at the time it is needed. For example, an optimal decision support system should be able to suggest an appropriate action that should follow when an order is placed. Such orders have been called *corollary orders* [10]. At the University of Wisconsin, with our strong dairy orientation, we call these "Commonly Ordered With" or "COW" orders. An example is suggesting an order to measure serum creatinine when a CT scan with contrast is ordered. Although house officers know that a serum creatinine should be drawn within a few days before a radiologic contrast study to identify renal insufficiency, it is easy to forget to order this test. To ensure the test is ordered, we designed our CPOE system to check the patient's recent laboratory results for a creatinine level and, if not present, to add an order to measure creatinine to the CT-ordering screen (**Figure 1**). This avoids the frequent occurrence at hospitals with paper-based ordering systems of canceled procedures because the creatinine is not available.

Another recommendation by Bates et al [9] is to ensure that suggested alerts, guidelines, and algorithms are integrated into existing clinical workflow. As a way to fit into our users' workflow, we decided to put the pharmacy and therapeutics (P&T) committee's antibiotic order form online whenever an antibiotic is being ordered. The house staff appreciates not

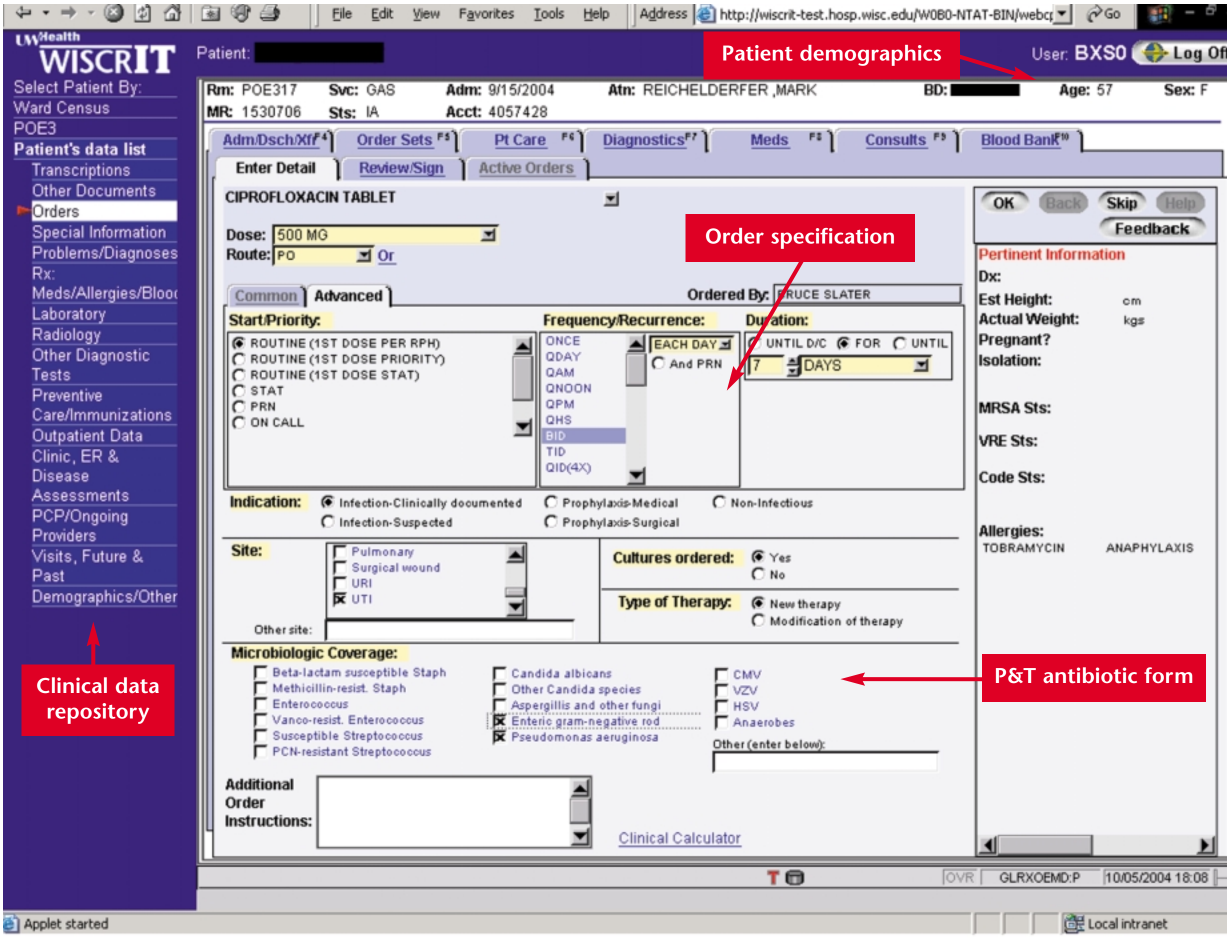

Figure 2. Example of integrated workflow. As an order for ciprofloxacin is specified, with a few clicks the user can simultaneously complete the antibiotic form required by the institution's pharmacy and therapeutics (P&T) committee. The patient's identifying information is available at the top, and links to clinical information in the clinical data repository are on the left.

needing to leave their workstation and to search for and fill out the paper antibiotic form as a separate step when ordering an antibiotic (**Figure 2**).

How Does CPOE Promise to Improve Care?

In *Crossing the Quality Chasm*, the second of its reports on problems undermining the U.S. health care system, the IOM defined quality health care as safe, effective, patient-focused, timely, efficient, and equitable [2]. The IOM acknowledged that to achieve this level of care requires systemic change in the ways that care is organized and delivered and in the environment in which it is provided.

One of the IOM's recommended strategies for achieving quality care is to invest in an information infrastructure to support the processes of care delivery, quality measurement and improvement, health services research, and clinical education [2]. Although CPOE is only one component of the information-rich health care system envisioned by the IOM and others, it has powerful capabilities to assist in reducing medical error, promoting evidence-based standards of care, and reducing costs—among other proposed benefits (**Table 2**). It is important to note that for a hospital to realize the full value of CPOE, the order entry system must be well designed and integrated into the workflow process and equipped with effective decision support features that physicians can and will use.

The following discussion provides examples of how CPOE can be applied to clinical care processes to improve the safety and outcomes of patient care. In hospitals where CPOE systems are in place, residency programs also can take advantage of these tools to provide opportunities for competency-based training of house staff (*see sidebar on page 51*).

Improve Medication Prescribing

Among the most serious problems with medication prescribing are medication errors. Such errors include selecting or administering the wrong drug for a condition; selecting or administering the drug at the wrong dose or frequency or by the wrong route; and failing to recognize potential drug allergies, side effects, or drug interactions. Medication errors are common, occurring at a rate of more than 1 million per year in U.S. hospitals [11]. They also are expensive, adding an estimated $2 million per year to hospital costs nationwide [12]. But most importantly, medication errors can be deadly. According to the IOM's first report, *To Err is Human,* medication errors contribute to 7000 patient deaths per year [1].

A growing body of evidence suggests that use of CPOE systems may reduce the potential for medication errors and improve the quality of medication prescription. In addition to eliminating errors due to illegible or misinterpreted hand-written orders, an electronic medication order can be scanned for potential problems that would result if the drug were dispensed as ordered. For example, a CPOE system may be designed so that, to finish the order, the physician must document the reason for overriding a warning that 1) the drug interferes with other medications the patient is taking or 2) the patient has a documented history of drug allergy or other contraindications. Such a system would have prevented a repeat allergic reaction in Dr. Warner's patient, who previously reported a drug allergy. A CPOE system also can be equipped to scan for relevant patient characteristics (eg, advanced age, laboratory results) that conflict with the drug order as entered. For example, sophisticated algorithms can infer liver dysfunction from laboratory results and use this information to bring warnings to the physician as needed during prescribing.

CPOE systems that have positive clinical decision support features may further ensure appropriate drug prescribing by guiding appropriate choices and providing alerts and recommendations when the drug orders are entered [13]. For example, the system may present a menu of appropriate doses and frequencies from which to choose, thus preventing excessive or incorrect doses of drugs or excessive frequency of administration. The system also may provide supporting information, such as evidence-based guidelines for cost-effective drug use. An example would be a system that prompts improved matching of antibiotics to indications by applying evidence-based rules to microbiology laboratory reports and physician orders. For example, in the CPOE system at Dr. Barnett's hospital, if a urine culture grows *Pseudomonas*, the first recommended antibiotic is a fluoroquinolone with proven efficacy for treating pseudomonal infection (ie, ciprofloxacin). Since it is on formulary, ciprofloxacin is suggested above nonformulary and more expensive antibiotics (eg, gatifloxacin), in compliance with the hospital's P&T committee recommendations. This use of CPOE-based clinical decision support is an example of *counter detailing* or *academic detailing*, in which evidence-based recommendations are promoted to counter the effects of marketing efforts by pharmaceutical companies. Prescribers are encouraged to switch to an evidence-based formulary medication at the time they specify a nonformulary medication.

Table 2. Potential Benefits of CPOE Systems

Improve access to information (patient-specific, clinical) needed to optimize orders
Improve quality of ordering process (orders more complete, less potential for misinterpretation)
Minimize potential for medication errors and adverse drug events
Reduce potential for duplicate orders
Increase compliance with standard of care practice; reduce variation in practice
Streamline ordering process and minimize time to receipt of services
Improve hospital workflow (eg, by offering antibiotic form to be completed)

Promote Standard of Care Practice

If care is taken to develop clinical decision support tools based only on high quality evidence and locally accepted guidelines, championed by local thought leaders, CPOE can promote adherence to evidence-based standards of care. For example, evidence strongly suggests that β-blockers and aspirin should be prescribed for most patients admitted with an acute myocardial infarction (AMI). Although there are few contraindications for these therapies, national adherence to these best practices is nowhere near ideal. For example, β-blocker use for AMI in 16,869 Medicare patients was only 45% in 1995 [14]. A CPOE system can be equipped to suggest orders for β-blockers and aspirin early during the course of the patient's hospitalization, making it easier for physicians to do the right thing for AMI patients. Positive decision support also can suggest preventive

Value of CPOE Systems for Competency-Based Training

CPOE systems can support competency-based training of house staff in many ways, assuming this technology is in place. The potential value will vary with the system capabilities, of course. However, even a system equipped only with software to check drug orders offers residents an opportunity to develop and demonstrate skill in using CPOE technology to improve patient care.

With greater system capabilities, such as evidence-based clinical decision support, the application of CPOE to resident education expands. For example, standardized, well-designed evidence-based order sets can be developed for use in common clinical presentations to ensure that the most effective procedures are followed and interventions are applied. Such order sets could be used to teach residents appropriate evidence-based care processes for common clinical situations, thus helping to ensure that patients receive suitable orders for similar presentations by reducing variations in care [23]. For example, most physicians are aware that β-blockers and aspirin should be given to persons suspected of having an AMI. Low levels of compliance with this evidence-based practice can be improved by offering order sets for AMI that include orders for β-blockers and aspirin. It is possible that CPOE systems with decision support may also enhance resident education by repeatedly reinforcing evidence-based guidelines and recommendations at critical moments in the care process [13].

A CPOE system that is linked to an electronic medical record system can be an important source of patient data for quality improvement and research activities. With such CPOE capabilities, residency programs have an opportunity to involve residents in quality improvement projects that emphasize skills underlying competence in practice-based learning and improvement. For example, such systems could allow residents to:

- Track how many of their patients who were admitted with a specific diagnosis were discharged on appropriate medication (eg, patients with congestive heart failure and hypertension who were on an angiotensin-converting enzyme inhibitor, as recommended by recent guidelines [24])
- Identify cohorts of patients with similar diagnoses to assess their practice patterns against evidence-based care practices and, possibly, make changes to improve their care decisions (eg, audit patients admitted for surgery to determine the level of compliance with evidence-based recommendations for venous thrombosis prevention)
- Gather and analyze real-time data on individual patients and populations with chronic conditions to develop population-based approaches to disease management (eg, referral for annual retinal exams in diabetic patients)

interventions that may be forgotten by hurried physicians. For example, a system could be designed to recommend pneumococcal immunization for patients being discharged from the hospital, if the patients meet simple criteria. Offering both the order and a link to the evidence supporting the recommendation makes it easy for physicians to adhere to this standard of care practice. In another example, a CPOE system can be designed to display a recommendation to order heparin for deep venous thrombosis prophylaxis at the time an order for bed rest is entered, and rates of compliance with this recommendation can be tracked by the system [13].

The electronic translation of preprinted order sets can institutionalize practices that are accepted locally as well as supported by evidence. However, preprinted order sets are difficult to translate. As they are currently written, these order sets are amalgams of protocols, procedures, orders, and guidelines. During the translation process, these components must be sorted out and, in some cases, separated into subsets and links to the guidelines. Some interaction by the user is necessary to specify the condition of the patient so that appropriate recommendations can be made.

Reduce Costs and Improve Efficiency of Care

CPOE systems can promote cost-effective ordering in several ways, such as prompting use of a less expensive and equally efficacious medication, prompting use of a lower dose or frequency of a medication without loss of effectiveness, and alerting a physician that a test is potentially unnecessary because it was very recently performed. One of the simplest ways that a CPOE system can reduce drug costs is by encouraging physicians to use hospital formulary medications and to adhere to recommended frequencies of administration. Because the hospital's P&T committee has already analyzed available evidence on the efficacy and cost-effectiveness of formulary medications, the CPOE programmer's job is to implement formulary medications and recommended frequencies as preferred choices in the prescribing module. In an example of the latter, a hospital was able to save $60,000 per year by promoting the use of ondansetron at the recommended frequency of 3 times per day rather than the existing practice of 4 times per day for certain indications (personal communication, Steve Rough, Director of Pharmacy, University of Wisconsin Hospital and Clinics). When ordering laboratory studies, if the ordering physician knows the results of recent similar tests, the tests may not need to be ordered. If the computer can assemble the necessary information and present it at the right time, physicians have the information they need without additional testing and expense.

Finally, a well-designed CPOE system can reduce time to process orders, causing less delay in implementing care interventions. A CPOE system also can improve communication of patient-specific information by reducing the potential for errors of interpretation and transcription and by allowing all members of the care team rapid access to patient data. As pointed out in Dr. Warner's example, the transmission of paper-based orders from the physician to the clerk and ultimately to the hospital's information system depends on physically indicating an order is ready to be acknowledged and executed and getting the chart to the right place for that to happen. In the electronic world, these steps are instantaneous and built into the normal process, without the need for further effort on the part of the physician placing the orders.

What Evidence Supports Use of CPOE Systems?

We have come to expect evidence for new technologies that we adopt, and CPOE is no exception. Fortunately, pioneering institutions have been using CPOE in some form for 20 years and have studied the impact of CPOE on various patient care outcomes. A few of the most important studies reporting CPOE effects are summarized here.

Medical Error Reduction

Medication errors. Bates et al [15] examined the effect of CPOE on prevention of serious medication errors not intercepted by others in the care team after the medication order was written. The authors defined such errors as medication errors that resulted in injury or had the potential to cause an adverse drug event (ADE) and which were not intercepted before reaching the patient. In this study, the nonintercepted serious medication errors decreased 55% after implementation of the CPOE intervention, from 10.7 events per 1000 patient-days to 4.86 events per 1000 patient-days ($P = 0.01$). Preventable ADEs were reduced by 17%, and nonintercepted potential ADEs declined by 84%. There also were fewer actual ADEs, but the difference did not reach significance.

In another study, Bates et al [16] examined the impact of a CPOE system with decision support features (eg, drug-drug interaction and drug allergy warnings) on the incidence of medication errors. In this study, the authors examined all errors except simple missed doses. The CPOE plus decision support intervention was associated with an 81% reduction in medication errors ($P < 0.0001$). The authors reported significant differences in all major types of medication errors, including errors related to dose, frequency, route, substitution, and allergy.

Evans et al [17] studied the use of a computerized antibiotic-management program in 545 patients admitted to the intensive care unit over a 1-year period and compared processes and outcomes of care with those for 1136 preintervention patients on the same ward during the preceding 2 years. The antibiotic-management program consisted of a computerized decision support tool that was linked to an electronic patient record system. The authors reported that the use of the antibiotic-management program resulted in significant reductions in orders for drugs to which patients had reported allergies ($P < 0.01$), excess doses of antibiotics ($P < 0.01$), and orders in which antibiotics were mismatched with resistant organisms ($P < 0.01$).

Errors of omission. As previously noted, clinical decisions resulting in an order for an intervention sometimes should trigger an additional (corollary) order for a test or treatment important for monitoring or minimizing the effects of the initial intervention. For example, an order for heparin or warfarin should prompt orders to monitor clotting function, or an order for blood transfusion should prompt a type and crossmatch. Drug monitoring and preventive care orders have well-established guidelines, and although physicians are very familiar with these, they may not always remember to place the corollary orders. A CPOE system that presents corollary orders for physician approval can minimize the potential for errors of omission by avoiding the need for physicians to remember the relevant guidelines and then execute the orders. Overhage et al [10] published a convincing study demonstrating this impact of computerized guideline-based reminders for corollary orders that were automatically presented to physicians while they wrote orders. The study was conducted on an inpatient medicine ward over a 30-week period and involved 2181 patients randomly assigned to 48 intervention residents or a control group of 41 residents. The authors reported 46.3% compliance with drug monitoring and preventive care orders by intervention physicians compared with 21.9% compliance by control physicians ($P < 0.0001$).

Improved Prescribing Practices

CPOE with effective clinical decision support has been shown to be a powerful tool for improving prescribing practices. Shojania et al [18] examined the impact of a computerized guideline for appropriate vancomycin use that was displayed to physicians at the time a computerized order was placed. Because vancomycin is expensive and overuse leads to drug resistance, decreasing inappropriate use of the drug is an important goal. When a vancomycin order was entered, the intervention group of the study was presented with an adaptation of the Centers for Disease Control and Prevention guideline for vancomycin use. Although physicians could proceed with a vancomycin order, many reconsidered after the prompt. The intervention resulted in 32% fewer orders ($P = 0.04$) for vancomycin and 28% fewer patients started on the drug ($P = 0.02$), and the duration of vancomycin therapy was 36% lower ($P = 0.05$).

Teich et al [13] evaluated the impact of a computerized drug-ordering system on prescribing behaviors and found the system could promote significant improvements in prescribing practices. The CPOE system at Brigham and Women's Hospital displays warnings, reminders, recommended dose and frequency, and suggested alternatives as physicians enter inpatient medication orders. Among the findings reported by the authors postintervention were an increase from 16.1% to 81.3% ($P < 0.001$) in the use of the preferred oral histamine2-blocker (nizatidine), a decrease of 11% ($P < 0.001$) in the standard deviation of drug doses, and a decrease of 30% ($P < 0.001$) in the standard deviation of frequency of administration.

Improved Efficiency and Cost-Effectiveness

Although researchers primarily are interested in how CPOE can impact the outcomes of care, they also may examine process variables to see if there is a trend toward better final outcomes. Mekhjian et al [19] studied the impact of a CPOE system on delivery of care at an acute care hospital and a cancer hospital. Variables assessed included medication turn-around time, radiology procedure completion time, laboratory results reporting time, and timeliness of countersignature of verbal orders. The authors reported that the CPOE system was able to reduce medication turn-around time by 64% ($P < 0.001$), radiology procedure completion time by 43% ($P < 0.05$), and laboratory results reporting time by 25% ($P = 0.001$). In addition, uncountersigned orders were reduced by 34%. The authors also reported that severity-adjusted length of stay decreased by 0.2 day in the acute hospital; there was no change in the cancer hospital. Brief reflection makes this result seem reasonable. Stays in a cancer hospital may be strongly influenced by the underlying disease, which may progress unremittingly regardless of the processes used to facilitate care. In a general hospital, much of the delay may be due to getting tests performed, diagnoses made, and treatments started. Perhaps more of the delay in general hospitals may be amenable to automation compared with cancer hospitals.

In an early study at Regenstrief Institute, Tierney et al [20] compared inpatient charges and total hospital costs for patients whose care was supported by a CPOE system linked to a comprehensive electronic medical record system to charges and total costs for patients managed by control medical teams. The authors reported that inpatient charges were $887 (12.7%) lower per admission for intervention teams, with significantly lower bed charges, diagnostic test charges, and drug charges. In addition, mean length of stay was 0.89 day shorter for patients whose care was delivered by intervention teams.

If CPOE Is So Great, Why Aren't We Using It?

Current Use of CPOE

Despite growing interest in CPOE and belief that its use can lead to improved patient care, only a small minority of hospitals currently have implemented CPOE. In a 2002 survey of U.S. hospitals, of the 626 respondents, 60 (9.6%) reported having CPOE completely available and another 41 (6.5%) reported partial availability, with the remaining 83.7% of hospitals reporting no availability [21].

Academic institutions have fared better than community hospitals in adopting CPOE. Perhaps one reason for this is that an academic hospital invariably *employs* the physicians and clinical trainees at the hospital. In addition to being oriented to research and new technology, attendings and house staff at academic hospitals are to a certain degree a captive audience and can be compelled to use a newly installed CPOE system, even when it means a short-term increase in workload. Because a Veterans Affairs (VA) hospital is an integral part of many training programs, many residents and recently trained physicians have had experience with the largest established CPOE system in the world. Although surpassed in some details by commercial and locally developed systems, the VA system (VISTA/CPRS) compares well with these systems in side-by-side tests [22].

Factors Critical to Success of a CPOE System

Implementing CPOE is difficult and expensive. To realize the benefits of CPOE, an organization must be willing and able to devote significant financial, human, and technical resources to ensure that a system is well designed and integrated into the existing clinical workflow and that users are educated in the use of the system and supported after system implementation. Importantly, the organization must be committed to change management and prepared to overcome the formidable hurdle of resistance to changing what is done (process of care delivery) as well as how it is done (culture of practice). Equally important is an institutional commitment of sufficient funds to support a multi-year effort.

Strong physician executive leadership and active involvement by physician champions are key to successful implementation of a CPOE system. Failure to have physician leadership behind the project and involved in the design of the software applications is a recipe for disaster. Equally important is the acceptance of the software and process changes by physicians who must use CPOE on a daily basis. User buy-in is difficult to establish. Clinicians must be enthusiastic about the vision of reduced errors, higher quality care, and effective decision support before the first rollout takes place. If CPOE can be shown to improve the information available at the time of decision making, implementation may go smoother. Physicians dislike making patient care decisions without having all the information they need to do it properly. Finally, if physicians are asked for feedback during the development and implementation of the system, they may be more likely to believe in the potential benefits of CPOE and be willing to suffer some bumps in the road.

Attention to details in the design and technological capabilities of the CPOE system and its applications also is critical. The system must be fast, reliable, integrated with other HIS components, and available at any time and from any workstation—and, ideally, from outside the hospital (home, office). Modern CPOE systems require the highest level of network capacity and availability, high-end redundant servers, and the latest mainframe computing technology. Software applications must be able to be customized to fit local practice workflow. Successful design and installation of a workable CPOE system requires careful analysis and a clear understanding of the practices of various clinical departments to ensure the software applications run smoothly and fit the hospital. Finally, these systems are not self-explanatory, so user training and support during and after implementation should not be overlooked.

Considerations for New Physicians

Physicians-in-training who are interested in CPOE and who plan to seek a job involving significant hospital work should include HIS capabilities on the list of things to consider when visiting a potential hospital employer. Although perhaps not the primary factor in deciding whether a clinical position is right for you, knowing the state of the hospital's information infrastructure will let you know whether CPOE is available and, if so, how well it is working.

How can outsiders on a brief visit to an institution determine whether a hospital's electronic systems, including CPOE, will be a help or hindrance in their practice? When requesting an interview, be sure to include time with the proper people to evaluate the computer systems that you would be using on a daily basis for years to come. Hesitance to show this part of the working environment or to make the necessary personnel available for questions is cause for concern. CPOE is a complex amalgam of software and process change. Seeing what is currently functioning and what is solidly on track to be implemented in the next year or two should be an integral part of your evaluation of a potential position. **Table 3** lists some important considerations for assessing a potential employer's likelihood for success with CPOE.

Conclusion

Integration of CPOE systems at the point of care is increasingly regarded as an important step toward addressing the quality problems in health care. By providing feedback and suggestions to physicians at the moment orders are entered, CPOE systems have the potential to prevent medication errors, to increase the likelihood that patients receive timely and appropriate evidence-based care, and to reduce costs related to unnecessary or inappropriate tests or treatments.

Table 3. Assessing the Electronic Infrastructure of a Potential Hospital Employer

Were physician users (attendings, house staff) involved in designing the information system and giving feedback to designers?
Is there adequate financial, executive, and leadership support for the project?
Are there enough technical personnel and up-to-date software licenses?
Does the flow of the software fit the way that you write orders and make rounds?
Are there enough workstations in the right places to enter orders whenever they need to be placed?
Does the software check for drug-to-drug interactions and drug allergy adverse events?
Is the CPOE system part of a comprehensive repository of results to inform decisions?
Are there easily available evidenced-based guidelines, textbooks, and context-specific help that applies to where you are in the ordering process?
Is there a rich variety of order sets backed by a process to keep order sets up to date and revised with the latest evidence?
Do users appreciate the system, even if it takes more time than a paper system?
Where is the hospital in the long-range plan of implementing information systems?
In what way will the information system be different in a year compared with what you are seeing now?

After years of quiet development and study, a groundswell of highly functional CPOE software is proving its worth and gaining mainstream acceptance. Although large gaps remain between current systems of health care delivery and the ideal practice environment enjoyed by Dr. Barnett, CPOE systems are widespread enough that many residents will be exposed to them during their training, particularly at VA hospitals. These well-informed physicians may wish to seek practice opportunities that offer the benefits and proven safety advantages of well-designed and effective CPOE systems.

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